BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT 230

BMR MICROFORM MF159

GEOLOGICAL BRANCH ANNUAL SUMMARY

OF ACTIVITIES

1980

Chief Geologist: J.N. Casey

DEPARTMENT OF NATIONAL DEVELOPMENT AND ENERGY
Minister: Senator The Hon. J.L. Carrick
Secretary: A.J. Woods

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
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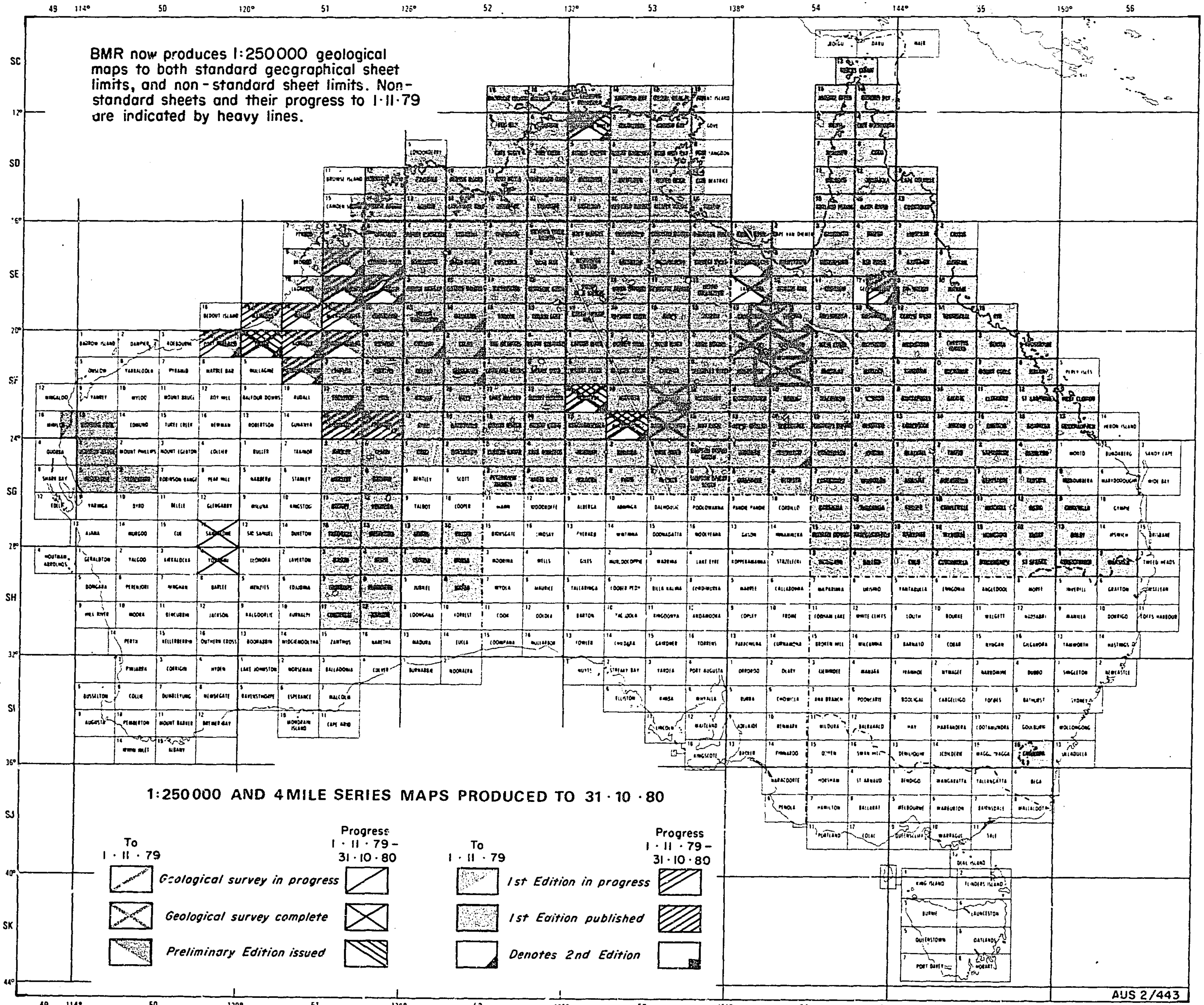
Published for the Bureau of Mineral Resources, Geology and Geophysics
by the Australian Government Publishing Service

ISSN 0084-7100



Report 230

ANTARCTICA

1:250000 SERIES MAPS

PRELIMINARY EDITION ISSUED - TO 31·10·77

BEAVER LAKE
CROHN MASSIF
CUMPSTON MASSIF
FISHER MASSIF - MOUNT HICKS
GOODSPEED NUNATAKS
MAWSON ESCARPMENT NORTH
MAWSON ESCARPMENT SOUTH
MAWSON - MOUNT HENDERSON
MOUNT CRESSWELL
MOUNT MENZIES
MOUNT TWIGG
OYGARDEN & LAW PROMONTORY
STINEAR NUNATAKS
WILSON BLUFF

No maps were issued in period 1·11·77 to 31·10·80

ENDERBY LAND FIELD STUDIES

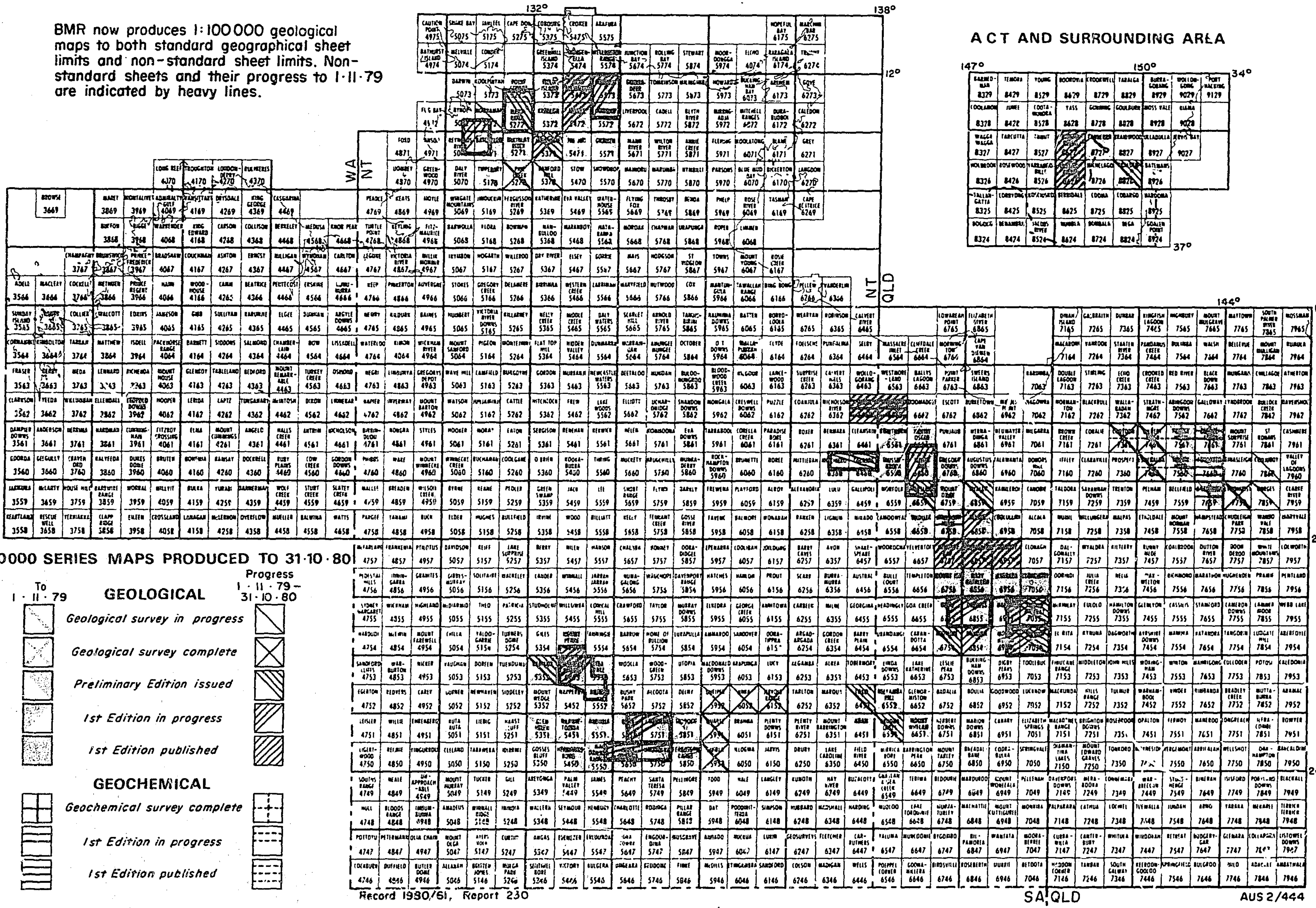
Geological mapping - Summer 76/77

Geochronological and structural studies - Summer 77/78, 79/80

AKER PEAKS
CAPE BORLEY
DISMAL MOUNTAINS
HANSEN MOUNTAINS
Mc LEOD NUNATAKS
MOUNT CODRINGTON
MOUNT RIISER-LARSEN
NYE MOUNTAINS
PROCLAMATION ISLAND
RAYNER PEAK
SANDERCOCK NUNATAKS
SIMPSON PEAK
TANGE PROMONTORY

FRONTISPIECE (1)

BMR now produces 1:100 000 geological maps to both standard geographical sheet limits and non-standard sheet limits. Non-standard sheets and their progress to 1·11·79 are indicated by heavy lines.



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GENERAL SUMMARY

This Report generally covers the period November 1979 to October 1980.

SEDIMENTARY SECTION

by

G.E. Wilford

Energy-related projects again occupied more than half of the Section staff during the year. Contributions were made to the multidisciplinary Central Eromanga Basin Project in the form of selection of material for petroleum source rock studies and the sampling of artesian water for traces of hydrocarbons and chemicals associated with hydrocarbon accumulations. The joint BMR/CSIRO, partly funded by the National Energy Research & Development Demonstration (NERDD) Program, projects to study the Permian coals of eastern Australia and the Toolebuc Formation oil shale both got underway after delays arising from staffing restrictions.

The preparation and publication of syntheses of information on sedimentary basins continued; a Bulletin on the geology of the Carpentaria and Karumba Basins (No. 202) was published, and Bulletin texts with their accompanying geological maps describing the geology of the Wiso (No. 205), Officer (WA part, No. 206), and Ngalia Basins (No. 212) are either in press or with the editors. A geological map of the Canning Basin at 1 000 000 scale is being prepared following the preparation or publication of all but three of the thirty-one 1:250 000 scale geological maps and accompanying explanatory notes that cover the basin.

Remapping at 1:100 000 scale of the Canberra 1:250 000 Sheet area was completed. Of the six 1:100 000 sheets involved, MICHELAGO* and BRAIDWOOD have been published by the Geological Survey of New South Wales, TANTANGARA and BRINDABELLA were published during the year (BMR Bulletin 204), ARALUEN was issued as a preliminary edition, and CANBERRA was being drafted. The geology of this part of the Lachlan Fold Belt is complex, requiring detailed structural, petrographic, geochemical, and geochronological studies for its elucidation.

Sedimentological, palynological, and palaeomagnetic studies of Cainozoic sequences and events in the Alice Springs region continued following field investigation in 1979. Pollen from lignite-bearing sequences indicate the presence of grassland and, perhaps locally, rainforest vegetation there in mid-Eocene times. A climate with alternating wet and dry seasons about 30 million years ago is indicated by a widespread laterite of that age developed on the basement rocks.

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*Names of 1:100 000 Sheet areas are printed in capitals.

Progress with a pilot period study of the Oligocene included the design of a data base and the input of data for the Murray, Gippsland, and Bass Basins and from the Arafura Sea area, and the preparation of isopach maps for the Bass Basin.

The joint BMR/States study of the hydrogeology of the Murray Basin accelerated as data provided by the State Geological Surveys and water authorities were compiled and correlation problems revealed. A computerised bibliography of the Murray Basin was completed. Work started on a 1:1 000 000-scale geological map and an assessment of the hydrocarbon prospectivity of the sedimentary sequences beneath the Murray Basin.

Documentation of various aspects of the study of the Great Artesian Basin, which began in 1971, was virtually completed during the year. Studies of the isotope hydrology, in co-operation with the Australian Atomic Energy Commission (AAEC), continued. To date these studies have given information on groundwater flow rates and past climate changes.

The photogeology and remote sensing group continued to assist in the interpretation of colour air photographs for major field projects and in applying Landsat data to geological problems. Training courses were organised both in Australia (Australian Mineral Foundation, AMF:Adelaide) and in Indonesia, the latter as part of the Irian Jaya Geological Mapping Project.

Great Barrier Reef studies were extended to the area off Townsville after four years of research in the southern part of the reef. The work is partly supported by Australian Marine Science & Technology Advisory Committee/ (AMSTAC/FAP) funds, and comprises shallow seismic profiling, sediment sampling, water monitoring, mapping of surface features, and shallow augering. The data are providing an insight into the patterns of reef growth and diagenesis, which have important implications for the interpretation of features in ancient reefs.

A review of information on manganese nodules in the Australian region indicated that only the 1 million km^2 Cape Leeuwin field, southwest of Western Australia, has any resource potential, but that metal values there are significantly below those of the eastern Pacific fields.

A study commenced, in co-operation with the Federal Republic of Germany, to investigate the superficial deposits on the continental shelves off northern New South Wales and southern Queensland with the aim of providing a stratigraphic framework for locating possible offshore accumulations of heavy minerals. Work, using the research vessel Sonne, comprised seismic reflection profiling, dredging, and coring.

The Palaeontological Group again made substantial progress in decribing, curating, and expanding the national fossil collections, in addition to providing specialist support for some major field projects. Publications marking the completion of major studies include Bulletins 186 (Late Cambrian trilobites from the Chatsworth Limestone, Western Queensland), 189 (Palynology of the Lower Cretaceous in the Surat Basin) and 190 (Conodonts from the Fairfield Group, Canning Basin, W.A.); the results of other studies were published in the BMR Journal and outside publications. In addition to long-term studies of particular fossil groups, considerable effort was assigned to examining and reporting on fossiliferous material from Papua New Guinea, Irian Jaya, and from company exploration drilling. One member of the group spent several months in Indonesia helping to establish a laboratory for the preparation and identification of macrofossils. A second member was seconded to the Economic and Social Commission for Asia and the Pacific (ESCAP) in Bangkok for two months as stratigrapher to co-ordinate the International Geological Correlation Program (IGCP) project 32, to produce an atlas of stratigraphic columns for the ESCAP region.

METALLIFEROUS SECTION

by

K.R. Walker

The main emphasis of work continues to be in the mineral province and mineral deposit studies comprising field and laboratory investigations.

Province studies are in progress in north and northwestern Queensland jointly with the Geological Survey of Queensland, in the Pine Creek Geosyncline and Arunta Block in conjunction with the Northern Territory Geological Survey, and in the Yilgarn and Pilbara Blocks in association with the Geological Survey of Western Australia. BMR geologists seconded to the Australian National Antarctic Research Expeditions (ANARE) have continued to carry out much of the geological field research in Australian Antarctica.

The Metalliferous Laboratory supports all field research with specialist petrological, geochemical, and geochronological studies; studies have included requests from State Surveys for assistance, such as isotopic dating to establish the Cambrian/Precambrian boundary in Western Tasmania, and in New South Wales to establish the age of deformation in the Cobar Supergroup.

The year has been a productive one; about 200 reports, publications, and maps have been issued or are in the final stages of preparation. Many long-term projects such as the Mount Isa/ Duchess, Arunta, Alligator Rivers, and Georgetown Inlier studies are nearing completion. Study continues on some adjoining areas: the Lyndhurst Project extends geological understanding of rocks of the Georgetown Inlier to the southeast, and study in the Pine Creek Geosyncline (PCG) is now concentrated in the west around Pine Creek and in the Cullen Granite area.

Progress in maps accompanying the mineral province studies are shown in Frontispieces 1 and 2.

In central Australia field research in the Arunta Block has been in the southern half of the Huckitta 1:250 000 Sheet area. It was found that the Delny-Mount Sainthill Fault juxtaposes contrasting rock types: those to the north are like those in the northern Alcoota 1:250 000 Sheet area, and those to the south are like rock units in the southern Alcoota, Alice Springs, and Illogwa Creek 1:250 000 Sheet area. The three-fold stratigraphic subdivision applied throughout the Arunta Block was found to be applicable also in Huckitta.

In the PCG Project, emphasis has been on petrological study of rocks from McKinlay, on fieldwork in PINE CREEK, RANFORD HILL, and NOONAMAH, and on granitoid rocks and associated mineralisation in the Cullen Mineral Field. Thirteen granitic phases have been identified in the Cullen Granite. In sedimentary sequences the role of evaporites in uranium ore genesis is being examined. Laboratory studies on uranium ore genesis have focused on Nabarlek, where recent mining operations have afforded the opportunity to collect representative samples of both ore and host rock. Work has continued on studies of a biogeochemical exploration method for uranium at Ranger; and on a geochemical and petrological study of the lower Proterozoic unmineralised metasediments in the PCG. Office work has been directed at the preparation of maps, Commentaries and Explanatory Notes covering the Alligator Rivers Uranium Field, and seven papers reporting some of the results of this project were published in the International Atomic Energy Agency (IAEA) volume 'Uranium in the Pine Creek Geosyncline'.

Some of the most significant results to come from the Mount Isa Project have been the understanding achieved of the geology of a rifted continental margin, and of the chemistry and geochronology of the acid volcanic sequences. The latter studies have resolved some of the differences which existed in the interpretation of the region. The Standish Volcanics have been shown to be equivalent to the Leichhardt Metamorphics. Some enigmas remain, however, particularly in relation to the range of U-Pb zircon ages obtained for the Corella Formation.

Geochemical study of the granites and their intrusive history is leading to a better understanding of the nature of the deep crust in the Mount Isa Inlier, which in turn has aided the correlation of acid volcanic and intrusive igneous events. A laboratory study of the regionally metamorphosed Proterozoic rocks of the Selwyn Range area has shown that metamorphism is of low-pressure type and of greenschist, lower to middle amphibolite, and middle to upper amphibolite facies, similar to other areas near Cloncurry and Mary Kathleen.

Progress in the Georgetown Project saw geological and geochemical field work completed west of Georgetown, in areas mainly of Croydon Volcanics, Inoruni Sandstone, and Esmeralda Granite. Particular attention was paid to mineralisation associated with the igneous rocks, and to refining knowledge of the stratigraphy of the volcanic sequences. To the southeast of Georgetown the Lyndhurst party concentrated on gaining an understanding of the Einasleigh and 'Balcooma' metamorphics and their relation to mineralisation. Completion of the stream-sediment sampling program covering most of the Georgetown Inlier is expected to provide interesting results relating tin and uranium distribution to particular geological units. In the office good progress has been made in the preparation of a Georgetown Special 1:250 000-scale colour-edition map and an accompanying report synthesising the geology of the Inlier.

Steady progress has been made in reporting Antarctic geological work and a summary paper has appeared in the Journal of the Geological Society of Australia. Fieldwork was limited this year to further sampling for isotopic dating studies, and one geologist participated in the GAVONEX 79 West German expedition to Northern Victoria Land. In the laboratories, geochronological and petrological work continues on specimens previously collected in Antarctica. Mafic igneous rocks from Proterozoic dykes in Enderby Land and MacRobertson Land, east Antarctica, have tholeiitic affinities, and the Phanerozoic intrusives and extrusives are mildly to intensely alkaline. Compositional studies were also made of felsic gneissic and granitic intrusives.

The Volcanology Subsection has been preparing the Cooke-Ravian Volume of Volcanological Papers (ed. R.W. Johnson), which is being published as a Geological Survey of Papua New Guinea Memoir; nine of the papers in the Memoir have been contributed by BMR colleagues of the late R.J.S. Cooke, some in joint authorship with him.

Various other special studies have been completed or are in progress in the Metalliferous Laboratory. These include a study of ophiolite and basalt petrogenesis on rocks from: the Papuan Ultramafic Belt; the Marum ophiolite complex; and the Wallaby Plateau, dredged during the Sonne cruise. The Wallaby Plateau basalts appear to be of 'transitional' or tholeiitic affinity, and compositionally are more consistent with oceanic than continental lithosphere.

Work continued on the alkaline ultramafic rocks, in particular on kimberlites. The study of various potential cryptoexplosion structures continued, and a petrological study was made of the BMR-Hollmayer meteorite collection.

Special studies on Western Australian rocks included an investigation of the Turee Creek uranium mineralisation, and the Pilbara volcanic geochemical study which is entering phase II, with sample collection for the project now covering the Warrawoona, Gorge Creek, Whim Creek, and Fortescue Groups. The results of phase I were reported in 1980.

In the main instrument laboratories 1990 samples were analysed for a total of 34 400 element determinations. In the X-ray diffraction laboratory 550 mineral determinations were made during the year.

The former Section Head, W.B. Dallwitz, retired in December 1979, after 32 years service in the Metalliferous Section.

GEOLOGICAL SERVICES SECTION

by

E.K. Carter

Fifty-four reports, papers, and maps (generally with commentaries) were issued, or in process of issue (i.e., submitted to supervisor) at the end of the period. This number includes some listed last year which were then in course of issue. Six reports, papers, and maps were published, and 17 are in press or process of publication; 25 Records and professional opinions were issued, and six are in process of issue.

The Engineering Geology and Hydrogeology Subsection continued a wide range of hydrogeological studies. Increased effort was put into research into the groundwater regime of fractured rocks in the ACT and environs, by an upgrading of data, implementation of a series of bore tests, and delineation of groundwater provinces; the study is continuing. A detailed study, jointly with the Division of Land Use Research (LUR), CSIRO, of the hydrological regime of the upper Yass River basin continued; sustained dry weather delayed the measurement of groundwater movement. Several investigations into the availability and exploitation of groundwater supplies were undertaken and six pollution studies were continued. Records of lake water conditions in Lakes George, NSW, and Windermere, Jervis Bay, and of groundwater in the Jervis Bay territory were maintained.

The study, for the Office of the Supervising Scientist, of the hydrogeological regime of the bedrock cover in the Alligator Rivers Region, NT, was not continued in 1980. The field program was completed in November 1979, and a report which recommended an ongoing program was completed. A pilot study, with LUR, CSIRO, was undertaken at Begargo Creek, Lachlan valley, NSW, to identify the distribution at depth and understand the origin of groundwater salinity. Analysis and interpretation of the results is continuing.

Estimation of the groundwater resources of Niue Island, South Pacific Ocean, based on 1979 fieldwork, was completed and further assistance given. A similar program was initiated for Kiribati, central Pacific Ocean; it promises to delineate adequate supplies of unpolluted groundwater.

ACT urban geology studies included an investigation of the route conditions for a proposed natural gas pipeline from Dalton to Canberra, further study of soil stratigraphy in the southern Tuggeranong district, and the completion of a geological report on the construction of the Ginninderra Sewer Tunnel. The first of a series of 1:10 000-scale engineering geology maps of Canberra, with notes, was printed; five others are in various stages of preparation. A 1:50 000-scale geological map of Canberra and Queanbeyan is with the printer.

Elsewhere, supervision of geological services and report-writing for Telecom cable tunnels in central Melbourne continued, and an assessment was made of a gravel deposit in northwest Tasmania.

Environmental studies involved comments on several environmental impact statements and a literature study, jointly with AAEC, of overseas developments in the disposal of high-level radioactive waste in geological formations.

In the Map Editing and Compilation Group 18 maps were edited (14 last year), and eight are in progress. Six maps and accompanying notes for the BMR Earth Science Atlas of Australia (three compiled by the Group) were published; others are in preparation. Revisions were made to the compilation, for the Atlas of Australian Resources, of a 1:5 000 000 geological map of Australia. A second draft of a 1:5 000 000 metamorphic map of Australia, under the direction of Professor T.G. Vallance, was compiled; the map and commentary will be published by BMR for the Commission for the Geological Map of the World. The first draft of a commentary on the 1:2 500 000 scale geological map of Australia (1976) was completed.

Recording of stratigraphic names and definitions and other information from current literature was maintained by the Central Registry staff. All information is recorded on a computer base and progress was made, with contract services, in transferring earlier records from cards to the computer base. The data base is becoming an important general geological information source. Five hundred and seventy nine new names and definitions were recorded, 235 names reserved, and 80 definition cards filed - a total of 894 (713 last year). Six lists of variations and one list of deletions were distributed.

The first draft of a data Record on the occurrence of fluorite in Australia, and a paper proposing a model for the deposition of fluorite, were written.

A depleted Museum staff maintained, at a reduced level, most of the normal activities of the Museum. Displays were provided for three interstate exhibitions and one local exhibition. Several hundred students, in school groups, visited the Museum and about 400 other visitors were received. Some fine mineral specimens were acquired by gift, exchange, and purchase.

More than 11 000 specimens for processing (thin-sectioning, chemical analysis, mineral or other determination, and dating) passed through the Transit Room (7 600 last year).

MULTIDISCIPLINARY PROJECTS

by

G.E. Wilford

Studies of the McArthur and Georgina Basins, in which staff from several Branches work together as a project team, continued during the year. The work of scientists from outside BMR is co-ordinated with that of the project team wherever feasible. K.A. Plumb has been responsible for project co-ordination in the McArthur Basin study and J.H. Shergold (1979) and C.J. Simpson (1980) for that in the Georgina Basin study.

Emphasis in the McArthur Basin Project has been on sedimentological laboratory investigations and the interpretation of geophysical data. Quarterly progress reports have been issued in the Record series, and tentative ideas on the structure of the southern part of the basin were aired at the BMR Symposium in April.

Significant results of the research include: the discovery of hydrocarbon residues in the 1600-million-year-old Looking Glass Formation; palaeontological evidence for the Early Cambrian age of the Bukalara Sandstone, and palaeomagnetic evidence for a revised mid-Carpentarian polar-wandering curve. Preliminary interpretations of geophysical data from the southern part of the basin are tending to confirm the geologically predicted form of the Batten Trough although there appears to be little gravity expression across the Emu Fault, which in part forms its eastern margin.

Emphasis in the Georgina Basin Project has been placed on publishing the results of earlier field investigations. Twenty three papers were published during the year and three 1:100 000-scale geological maps issued. Particular advances were made in re-interpreting the stratigraphy of the southern part of the basin, in sedimentological studies of the carbonate units, and in petroleum source and reservoir rock investigations. Interpretation of the aeromagnetic data from the Glenormiston area is yielding information on basement lithologies and structure.

The main effort in the central Eromanga Basin was geophysical: seismic and gravity surveys were undertaken to provide structural and stratigraphic information on the Eromanga and underlying basins. The new information is being integrated with good-quality seismic and gravity information obtained previously and with other geophysical and geological information, now being obtained by BMR and private companies, to assist in defining the structural and depositional history of the area and its petroleum resource potential. A series of mainly east-west regional multicoverage seismic reflection traverses was recorded west of the Canaway Fault to investigate the Eromanga Basin, the underlying Permo-Triassic Cooper Basin, and the Warrabin Trough, which contains Devonian sediments of Adavale Basin age. Geological contributions included the selection of material for petroleum source rock studies and sampling of artesian water for traces of hydrocarbons and associated chemicals. Geological results are also reported in the Sedimentary Section part of this Summary of Activities.

BAAS BECKING GEOBIOLOGICAL RESEARCH LABORATORY

by

A.R. Jensen

Research in the Baas Becking Geobiological Research Laboratory has, during 1980, continued to be mainly concerned with possible geobiological controls of base-metal sulphide mineralisation. In addition, however, work has continued on a NERDD Program-funded project aimed at investigating the potential of microbiological processes to enhance the recovery of liquid petroleum from natural reservoirs, and some research has been undertaken into general questions of geobiological processes in the Precambrian.

As in the past four years, research in the metals program has included field studies of modern sedimentary environments, mainly around Spencer Gulf, SA, ore genesis studies in the Adelaide Geosyncline and Stuart Shelf regions, SA, and laboratory studies as an extension of modern environment research.

Sedimentological research in areas marginal to Spencer Gulf has established the distribution and characteristic sediment facies of a number of prograding coastal complexes. Studies of various sedimentary structures and skeletal carbonate grains have thrown some light on diagenetic processes which in these subenvironments are largely controlled by the interaction of seaward-flowing continental groundwaters, and seawater.

Complementary geochemical studies in the Spencer Gulf area have established the role of groundwaters in the formation of iron minerals in an intertidal facies at Fisherman Bay. At the same time, there has been microbiological research into the environmental controls of the habit and growth rate of algal mats, and of the fate of organic carbon produced by these mats. Investigations are continuing into the amount of organic carbon which is potentially utilisable by sulphate-reducing bacteria under these conditions. Other microbiological studies have provided quantitative information on the combined effects of temperature, salinity, and organic carbon availability on sulphate reduction in marine environments, and a general equation containing these variables has been derived. Concurrent studies of the distribution of sulphur, deuterium, and oxygen isotopes have greatly assisted the integration of these sedimentological, geochemical, and biological studies.

Similar studies of geobiological processes in modern sedimentary environments have also been undertaken in places other than Spencer Gulf. Some have concentrated on lakes of Eyre Peninsula, SA, and on processes relevant to the formation and preservation of organic matter in saline lake ecosystems dominated by blue-green algae. Others have dealt with conditions applying in saline lakes in Antarctica, and at the bottom of a deep oceanic trench in the Indian Ocean.

The general aim of the ore genesis studies undertaken within the Laboratory is to determine the origin of various stratabound base-metal sulphide deposits and to ascertain which characteristics could serve as exploration guides. As a result of studies of mineralisation at Mount Gunson and Lake Dutton on the Stuart Shelf, it is concluded that copper mineralisation in the Pandurra and Tapley Hill Formations has involved the replacement of iron by copper transported to the site by brines. Studies of mineralisation in the Adelaide Geosyncline and at Mount Painter are continuing. In addition, isotopic studies have been undertaken to assess the possibility that the lead in stratabound deposits such as McArthur River was derived from the underlying sediments.

Sedimentological and biological studies within modern environments have continued to be augmented by laboratory-based studies where experiments are undertaken to assess the plausibility of models of various processes generated on the basis of field evidence. A principal activity in this field has been the monitoring of a system of tanks filled with sediment layers and brines of diverse salinities. During 1980 the studies have concentrated on the nature of diagenetic processes affecting organic matter in the organic, aragonitic, calcitic, and sandy layers of the sediment pile.

The study of the feasibility of microbially enhanced oil recovery is still at an early stage, but results to date have indicated enhanced recovery of an oil in a laboratory-simulated oil-wet system.

In addition to the normal Baas Becking program, M.R. Walter took part in a multinational Precambrian palaeobiology research project in California aimed at investigating the origin and early evolution of life and its geochemical effects. At the same time, G. Skyring and T.H. Donnelly have been examining the sulphur isotope composition of Precambrian sulphides and sulphates in relation to the evolution of the pathways of sulphate reduction in procaryotes.

SEDIMENTARY SECTION

Head: G.E. Wilford

PROVINCE STUDIES

BASIN SYNTHESES

STAFF: H.F. Doutch, P.J. Kennewell, M.J. Jackson, A.T. Wells, F.J. Moss (Geophysical Branch).

A Bulletin on the geology of the Carpentaria and Karumba Basins (No. 202) was published, and Bulletin texts and accompanying 1:500 000 or 1:1 000 000-scale geological maps describing syntheses of the geology of the Wiso (No. 205), Officer (WA part, No. 206), and Ngalia (No. 212) Basins are with the editors or in press. A start was made with the compilation of a 1:1 000 000-scale map of the Canning Basin. The status of the 1:250 000-scale geological maps and explanatory notes covering these basins is shown in Frontispiece 1.

CANNING BASIN MAPPING

by

R.R. Towner

STAFF: R.R. Towner, D.L. Gibson

The Canning Basin mapping project is a long-term co-operative study by BMR and the Geological Survey of Western Australia to collect, analyse, and interpret geological data in sufficient detail, in conjunction with subsurface geophysical and drilling information, to enable all outstanding 1:250 000 First Edition geological maps and accompanying Explanatory Notes to be prepared. Second Edition maps and notes of some Sheet areas are also to be published.

Systematic field investigation of the 31 Sheet areas comprising the Canning Basin was carried out yearly from 1972 to 1977. By the end of October, 1980, 17 Explanatory Notes and map were published, 11 were in press, and three were in preparation (see Frontispiece 1).

Record 1980/30, presenting preliminary data from the 1977 fieldwork on the west Canning Basin, was in press, and a start was made with the preparation of a 1:1 000 000-scale geological map of the Canning Basin.

LACHLAN FOLD BELT (CANBERRA AREA)

by

M. Owen, D. Wyborn, & R.S. Abell

The Lachlan Fold Belt project is designed to obtain a clearer understanding of the relation between sedimentation, magmatic activity, and mineralisation in the area; to assist in the revision of the Canberra 1:250 000 geological sheet; and to provide basic information for engineering geology investigations. The field research is done in collaboration with the Engineering Geology Group and the Geological Survey of New South Wales.

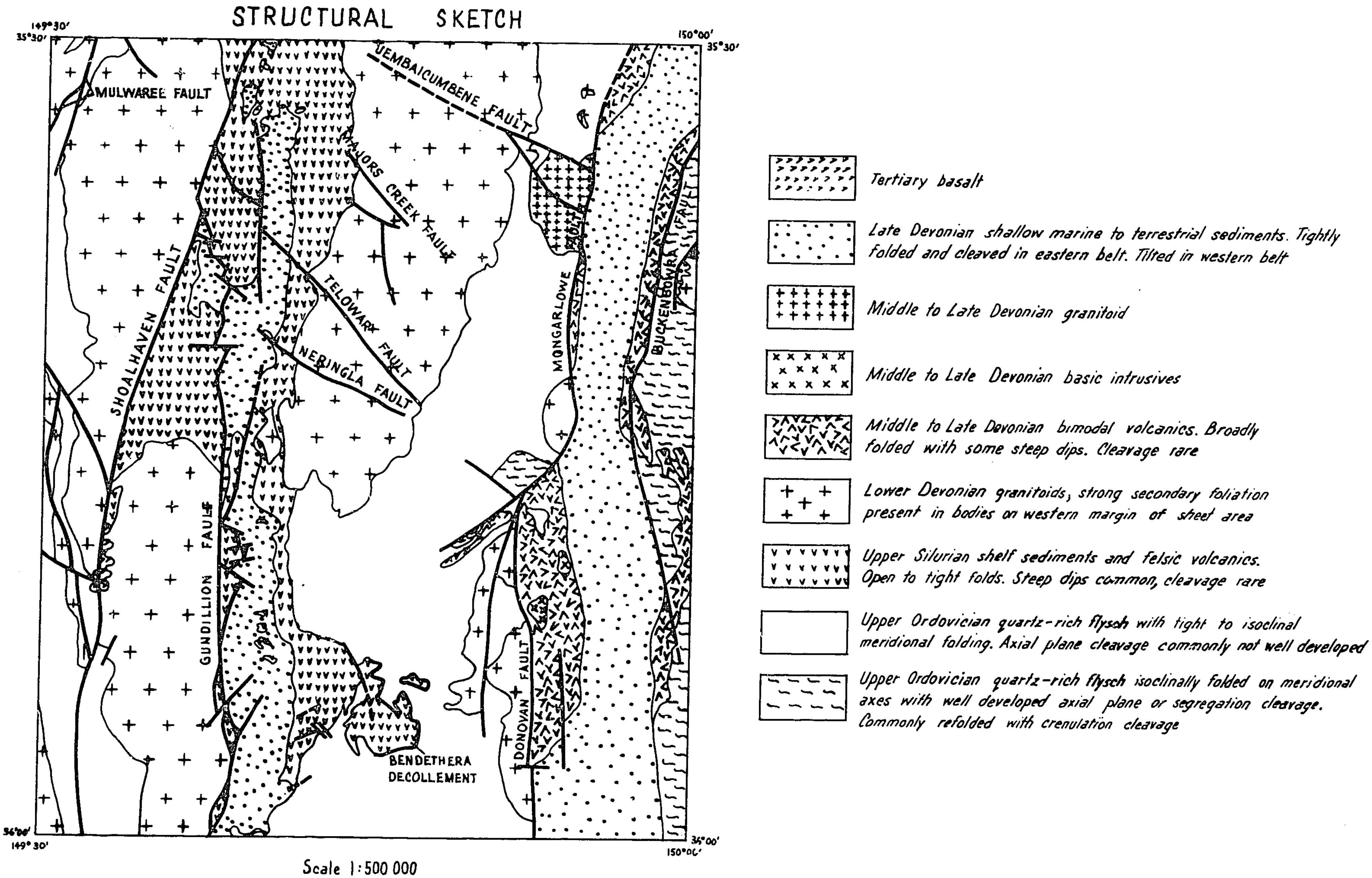
TANTANGARA-BRINDABELLA 1:100 000 SHEET AREAS by M. Owen

BMR Bulletin 204 on the geology and geochemistry of the two Sheet areas was published, together with the two First Edition colour maps.

ARALUEN 1:100 000 SHEET AREA by D. Wyborn & M. Owen

With the exception of some minor checking in a few areas, mapping has been completed and a preliminary 1:100 000 geology sheet has been issued for general use. A simplified map of the major rock units is shown in Figure S1. Follow-up petrography and geochemistry has now resulted in a reasonably good understanding of the rock relationships and geologica history of the area.

In the Late Ordovician, quartz-rich turbidites were being deposited in the area; palaeocurrent directions consistently show their source was from the south. Geochemical analyses of the turbidites show them to be not significantly different from those farther west in the Monaro Slope and Basin and those in the Wagga Trough. A section in Moodong Creek, where the turbidites are relatively unfolded and mostly dipping steeply to the west, is 3600 m thick and neither top nor bottom are exposed. In the Early Silurian, tectonic events to the south and west cut off the sediment supply, but the area still remained submarine. Further tectonic events in the Middle Silurian uplifted the area, exposing some parts and producing shallow-marine conditions in others. Upper Silurian clastics, interbedded with a number of limestone bodies, were deposited in the shallow seas but soon I-type felsic volcanism broke out, becoming subaerial as the sea rapidly retreated. The volcanism was brought to a close in the Early Devonian by intense deformation which produced tight folding in the sedimentary rocks, but much of the subaerial felsic volcanics east of Bendethera behaved



Record 1980/61, Report 230

I55/A16/2348

Fig. S1 Simplified geological map - Araluen sheet area

rigidly and a decollement developed between them and the underlying Ordovician sediments. This Early Devonian compressional episode delayed the intrusion of granitic bodies comagmatic with the Late Silurian volcanics until after the compression had dissipated. At least three suites of I-type granites were intruded. The western Boro Suite is characterised by a high quartz content, high Fe and Ca, and low Na and Sr. The central Braidwood Suite is characterised by high K, Rb, REE, Ba, and Sr, and plutons show compositional zoning typical of non-minimum melt magmas. The eastern Merricumbene Suite is high in Na and Sr and low in Fe. The three suites can be matched with suites identified by university researchers working in the Bega Batholith to the south.

The area was a landmass in the Early to Mid-Devonian. In the late Middle Devonian, extensional faulting and monoclinal flexing of the folded Ordovician rocks formed the Comerong Rift Zone on the eastern edge of the Sheet area. Partial melting occurred in the lithosphere beneath the rift zone, and the resultant tholeiitic magmas migrated into the crust, causing partial melting of the residual granulitic material left after the period of Late Silurian I-type magma generation. The resulting lower crustal melts were relatively anhydrous and fluorine-rich, typical characteristics of anorogenic or A-type magmas. Bimodal tholeiitic and A-type magmas intruded and erupted along the Comerong Rift Zone. The tholeiitic magmas intruded the upper crust in the form of latitudinally oriented dolerite dyke swarms well to the west of the Comerong Rift Zone, and extended as far west as Googong Dam, on the Queanbeyan River. The latitudinal orientation of the dolerite dykes well away from the Comerong Rift Zone gives way to meridional-trending dykes adjacent to the zone indicating a change in principal stress direction of 90°. Subsidence continued along the Comerong Rift Zone after volcanism ceased, and this favoured the accumulation of an extensive sheet of continental fluviatile, deltaic, and shallow-marine sediment over the whole area in the Late Devonian. In the Carboniferous, tilting and faulting occurred in much of the area underlain by granites, but the Comerong Rift Zone and the western edge of the Sheet area bordering the Late Silurian Captains Flat Trough were zones of weakness and were intensely folded and cleaved. Granites adjacent to the Captains Flat Trough were foliated during the deformation (but those farther east remained unstressed) and tight folds of Early Devonian age in the Ordovician rocks were refolded into downward-facing structures adjacent to the Comerong Rift Zone. A belt of downward-facing folds about 1.5 km wide has been traced along the eastern side of the Rift Zone from Quart Pot Creek in the south to Bimberamala River (ULLADULLA) in the north, a distance of over 30 km, and the downward-facing belt probably extends a further 20 km north-northeast to be lost under the Sydney Basin.

There is no evidence in the Sheet area of geological events in the Mesozoic, when the area was probably land in the process of being planated. In the Tertiary renewed activity occurred along old fault lines in association with the outbreak of alkali basalt volcanism. At Jerrabattgulla Creek, basalts dated at 19.1 ± 0.4 m.y. were extruded along a 5 km length of the active Shoalhaven Fault line; about 30 m of vertical movement has taken place along the fault since the basalts were deposited.

A geochemical comparison has been made between the Devonian basic rocks associated with the Comerong Rift Zone and Silurian basic rocks from outside the Araluen Sheet area associated with the Lachlan Fold Belt S-type and I-type granitoids (Micalong Swamp Basic Igneous Complex, Silurian dolerite dykes from the Canberra Sheet area, and the Lockhart Igneous Complex). Both suites show similar tholeiitic iron and titanium enrichment trends before alkali enrichment, but the younger suite is greatly enriched in incompatible elements such as K, Rb, Ba, Zr, P, and REE (for example, see Fig. S2). Although the Devonian suite was generated by smaller degrees of partial melting (as indicated by their becoming quartz normative at lower Mg number values than the Silurian suite for normalised Fe_2O_3/FeO ratios), this factor is not considered to be capable of producing the amount of incompatible-element enrichment observed. In addition, the early formation of primary hornblende in the Silurian suite compared with the persistence of clinopyroxene crystallisation to very low Mg number values in the Devonian suite clearly shows that the Silurian suite source was more hydrous. Experimental work indicates that the production of hydrous, relative to anhydrous, tholeiite requires greater depths of generation. We conclude that:- (1) the upper part of the lithosphere was not partially melted in the Silurian because the magma source was deeper; and (2) the upper part of the lithosphere remained enriched in incompatible elements despite the Silurian events and this area was partially melted beneath the Comerong Rift Zone in the Devonian.

CANBERRA 1:100 000 SHEET AREA by R.S. Abell

Eight 1:25 000-scale field compilation sheets (also available at 1:50 000 and 1:100 000 scales) were completed, together with a first draft report. The area covered by CANBERRA lies in the southeastern Lachlan Fold Belt, and includes sections of three structural zones (Scheibner, 1973*): the

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* Journal of the Geological Society of Australia, 20, 405-6.

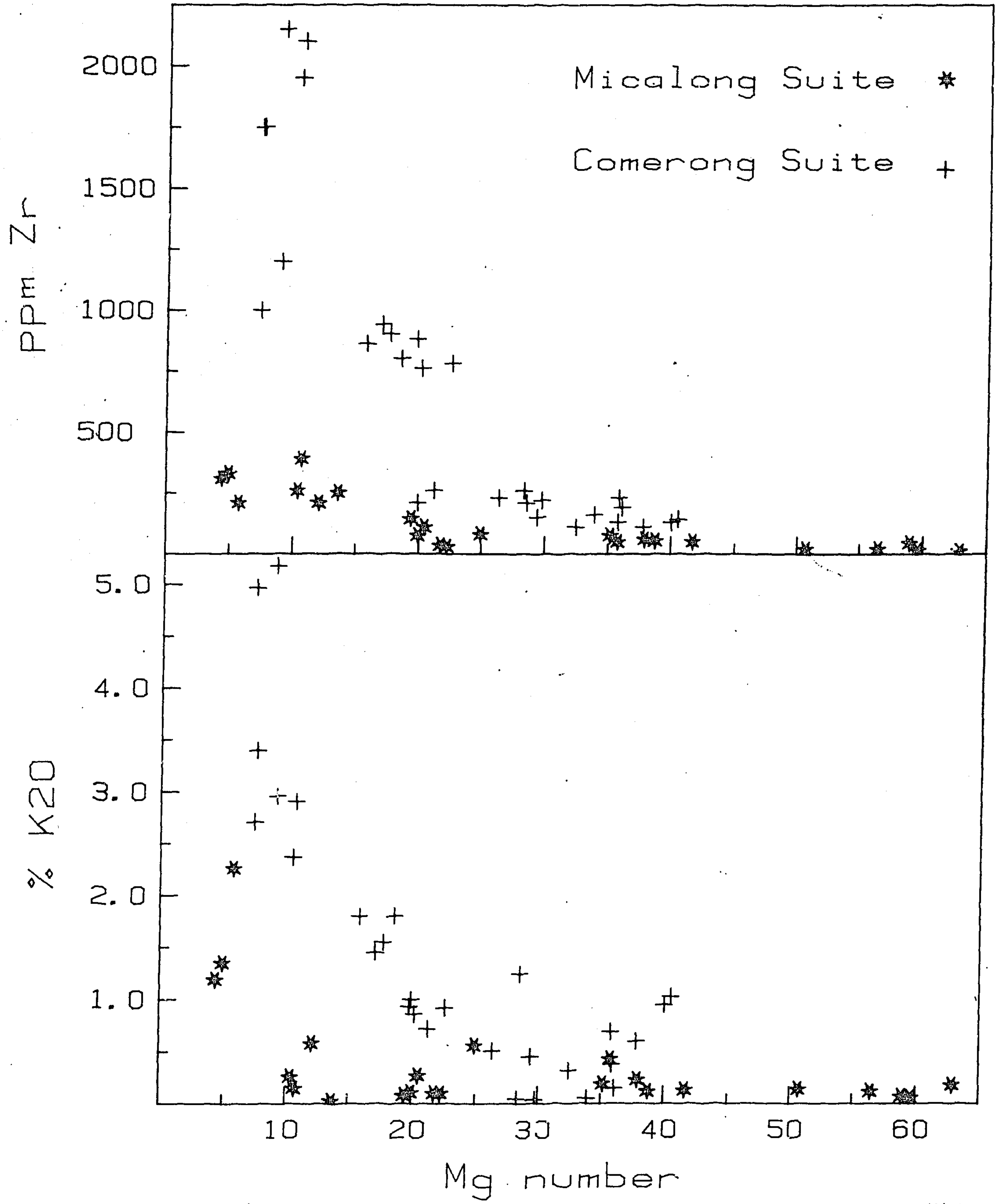

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Fig. S2 Comparison of fractional trends of two incompatible elements (zirconium and potassium) for the Silurian Micalong Swamp Basic Igneous Complex and the Devonian basic rocks of the Comerong Rift Zone

Cowra-Yass Synclinorial Zone, the Molong-South Coast Anticlinorial Zone and the Captains Flat-Goulburn Synclinorial Zone. These structural units, which are separated from one another by major meridional faults, broadly correlate with the horst and graben nomenclature of Strusz (1971)*. Palaeozoic rocks range in age from Ordovician to Early Devonian; Cainozoic sediments are present locally.

Deep-water marine sedimentation, represented by distal flysch derived from a landmass to the south, probably started in the mid-Ordovician (Darriwilian?) and reached its maximum development with the deposition of graptolite-bearing black shales of Gisbornian-Bolindian age. An F_1 deformation occurred at the close of the Ordovician, largely by gravity-type deformation triggered by instability on the Molong Volcanic Rise to the west.

During the Llandoverian, deposition from the west of a shallower-marine proximal flysch sequence occurred in the meridional-trending proto-Canberra-Yass Shelf. This was followed during the Wenlockian by an F_2 deformation which refolded the earlier gravity folds to give variably plunging isoclinal folds, a prominent cleavage, and low-grade regional metamorphism of greenschist facies.

Termination of the F_2 deformation signalled the onset of late Wenlockian-Ludlovian acid volcanism on the Canberra-Yass Shelf. Volcanism consisted of the widespread extrusion of thick ignimbrite sheets interspersed with shallow-marine terriginous and carbonate sediments and local phases of terrestrial erosion. Small intrusions of quartz-feldspar porphyry may relate to volcanic centres. The Captains Flat Trough was initiated at this time by crustal rifting, leading to marginal intrusions of dolerite and gabbro, minor extrusions of basalt, thin beds of felsic volcanics, and local deposition of proximal flysch sediments.

At the end of the Silurian a phase of granitic magma intrusion followed acid volcanism; this is most evident in the anticlinorial zones. Older S-type granites were emplaced in the west grading into younger I-types as the centres of intrusive activity spread eastwards.

After the Early Devonian an F_3 deformation brought sedimentation to a close. All rocks in the Captains Flat Trough were intensely deformed to give tight isoclinal folds and an intense cleavage-foliation. Farther west on the Canberra-Yass shelf the same deformation was milder, becoming gradually and locally more intense close to major fault zones.

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*Bureau of Mineral Resources, Explanatory Note to the Canberra 1:250 000 Geological Sheet, SI/55-16.

At the close of the F_3 deformation the area was exposed to peneplanation until epeirogenic uplift, which was mainly controlled along older meridional fault lines, started in the Early Tertiary. Alkali basalt flows which extruded over wide areas of the Lachlan Fold Belt during the Tertiary are absent from CANBERRA. Continental Tertiary sedimentation and weathering episodes occurred during quiescent intervals. Unconsolidated Quaternary sediments restricted to lacustrine and fluvial environments were deposited, largely in response to climatic changes associated with the Pleistocene Ice Age.

In an attempt to date more accurately Late Silurian marine sedimentation and acid volcanism, all limestone exposures in the Sheet area were sampled for conodonts. None of the limestones were barren, but age-diagnostic forms were not found. An impersistent limestone bed near the top of the Canberra Formation yielded high concentrations of conodonts which may be worth further sampling. Saddle dolomite and biohermal reef limestones occur at White Rocks, Queanbeyan.

Assembly of data on the Cainozoic sediments in the Bungendore-Molonglo plains area continued. Nine exploratory drillholes and water-bores were geophysically logged (gamma and neutron) to assist the NSW Water Resources Commission in their investigations to augment Bungendore's town water supply. From the logging it is now possible to pick accurately the thickness and nature of the Quaternary sediments and the top and thickness of the underlying Tertiary weathering profile extending into bedrock.

NORTH VICTORIA LAND (ANTARCTICA)

by

D. Wyborn

From December 1979 to February 1980, D. Wyborn carried out fieldwork with the first Federal German Antarctic Expedition in north Victoria Land (GANOVEX 1979-80). The aims of the project are to correlate the Palaeozoic history of north Victoria Land with events in the Lachlan Fold Belt, particularly in terms of sedimentation and granitoid genesis, and thus possibly refine the Antarctic-Australian plate reconstruction.

Fieldwork was very successful, and large number of samples was collected from a wide area. Much of north Victoria Land is underlain by a folded sequence of turbidites, the Robertson Bay Group, which differ from the Ordovician turbidites of the Lachlan Fold Belt in that they contain more detrital feldspar and calcite cement is common. The turbidites of the Lachlan Fold Belt were most likely derived by erosion of the Robertson Bay Group after they were folded during the Ross Orogeny. Chemical analyses for comparison of the two turbidite suites are in progress.

Granitoids of north Victoria Land are both S-type and I-type. The S-type granitoids are to the west of most of the I-type granitoids and appear to be related to anatexis, reaching relatively high levels in the crust during the Ross Orogeny. I-type granitoids to the east are mostly high level hornblende-biotite adamellites and granodiorites with contact aureoles in Robertson Bay Group turbidites. Published K/Ar dates indicate that they are probably of Devonian age.

CAINOZOIC STUDIES OF THE ALICE SPRINGS REGION

by

B.R. Senior

STAFF: B.R. Senior, E.M. Truswell, M. Idnurm (Geophysical Branch)

This project, commenced in 1979, is a multidisciplinary study of the sedimentation, age and weathering history of Cainozoic epicratonic basins. During 1980 lithological information was compiled from shallow stratigraphic drillholes for the southeastern part of the Ti Tree Basin (Alcoota 1:250 000 Sheet area) and from an unnamed Cainozoic sequence in the Illogwa Creek 1:250 000 Sheet area. Palaeomagnetic dating of laterite profiles developed in the Arunta Complex and Cainozoic rocks continued; further sampling is proposed for 1981. A carbonaceous sequence from the Hale Basin was found to contain a rich assemblage of probable middle Eocene palynomorphs. The stratigraphy of the Hale Basin is summarised in Figure S3.

SEDIMENTATION

Although there is marked gross lithological similarity between the sequences in the basins of the Alice Springs area, detailed correlation has been hampered owing to the weathered nature of many of the rocks and the lack of fossils. The Ti Tree and Waite Basins and the unnamed basin in western Illogwa Creek 1:250 000 Sheet area were formerly interconnected, as indicated by the subcrop distribution of rock assemblages. The Hale Basin evolved as an isolated feature but contains a rock sequence broadly similar to the other basins lying to the north and east of the Strangways and Harts Ranges. Of particular interest is an olive-green mudstone unit present in all basins. In the Hale Basin this mudstone grades upwards into a lignite-bearing carbonaceous sequence; both lignites and mudstone contain a rich flora of probable middle Eocene age. Elsewhere the basin sequences appear to be barren of palynomorphs.

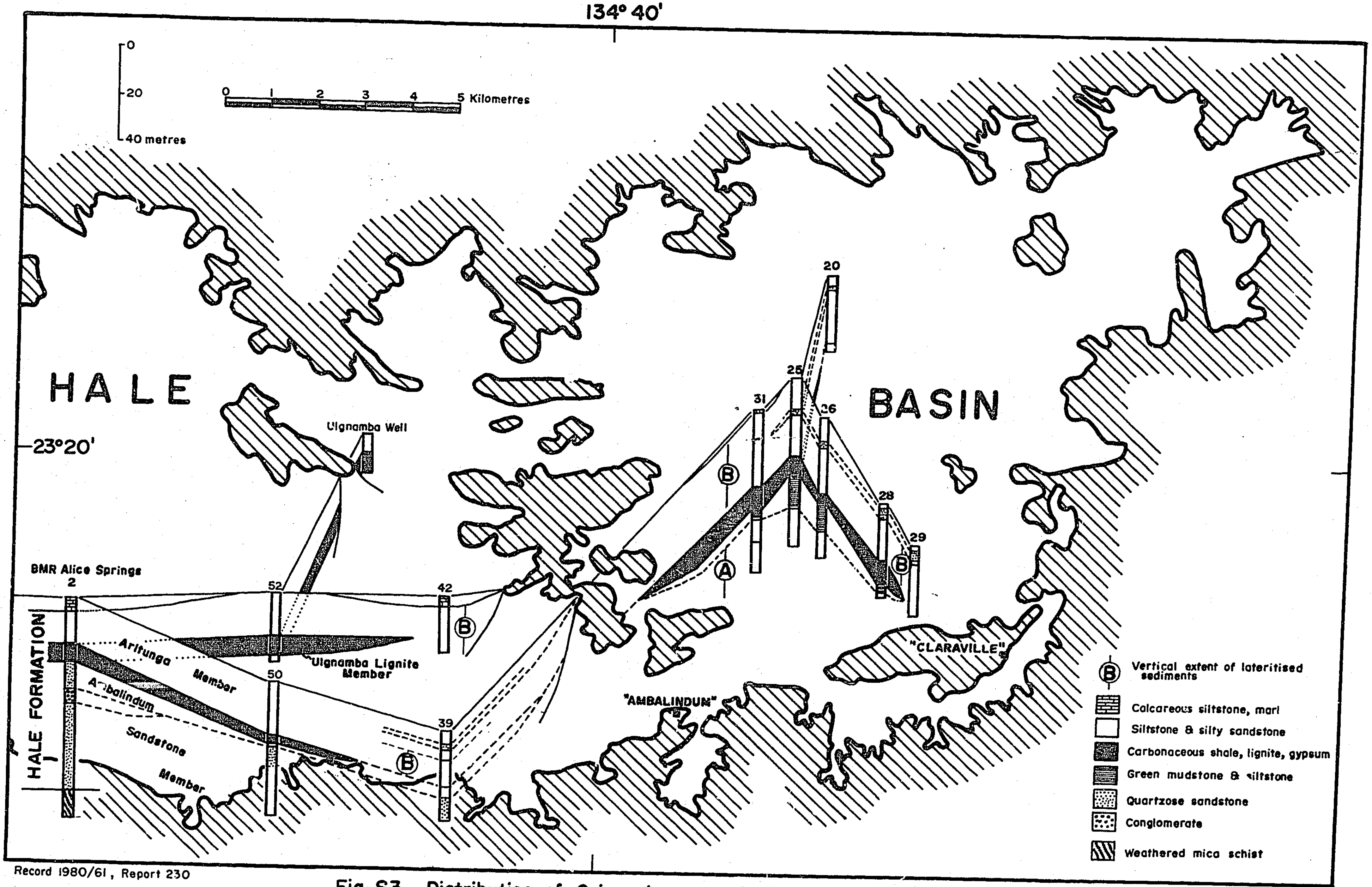

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Fig. S3 Distribution of Cainozoic rock units in the Hale Basin, N.T.

F53/A14/215

The widespread distribution of the olive-green mudstone indicates a possible time-relation between the Hale Basin and the other basins, and possibly represents the presence of interconnected lakes and swamps by the early Eocene. Post-middle Eocene rocks in all basins investigated consist of oxidised, coarse-grained, poorly sorted clastics which appear to have been rapidly deposited in coalescing piedmonts. Late Miocene vertebrate fossils indicate that lacustrine environments followed, and interbedded red and green clayey siltstone, sandstone, and carbonate accumulated. These rocks are now protected from erosion by resistant cappings of chalcedony forming low plateaus bounded by steep scarps.

PALAEOMAGNETIC DATING OF LATERITES

Widespread laterite that has developed in gneissic rocks of the Arunta Complex was dated palaeomagnetically at about 30 m.y. This laterite profile appears to be also present in the Cainozoic basin sequences, but field checking is required to substantiate this. Arunta Complex rocks encountered in drill-holes below the Cainozoic sequences contain yet another deeply weathered profile, indicating a widespread weathering event before sedimentation. This earlier weathering event may be related to the 60 m.y. deep weathering episode that was dated palaeomagnetically in southwest Queensland.

PALYNOLOGICAL IMPLICATIONS

Palynological investigations in the Hale Basin have provided both age control and climatic information. Pollen assemblages from the lignites and the underlying green mudstones contain, as very rare elements, pollen types that are confined to the mid-Eocene in southern Australian coastal basins. If these types have a similar time range in this northerly locality, then their presence in the Hale Basin in assemblages which are dominated by *Nothofagus*, the southern beech, and pollen of a number of podocarpaceous genera, indicates that rain-forest trees grew nearby. Grass pollen occurs in all assemblages, however, so that there was some open vegetation, possibly on lake margin sites. A maximum observed frequency of the grass pollen of seven percent is in excess of that found in contemporaneous coastal deposits, and can be interpreted as evidence that grasslands may have evolved earlier in the interior of the continent. The grassland flora indicates intermittent dry phases, either seasonally or less regularly, in an otherwise wet climatic regime.

CENTRAL EROMANGA BASIN PROJECT

by

B.R. Senior & M.A. Habermehl

The Central Eromanga Basin Project aims to carry out fundamental multidisciplinary geoscientific investigations of the Eromanga Basin and underlying sedimentary basins. Program proposals are detailed in Harrison & others (1980)*. The study involves a review of existing geological and geophysical information, together with acquisition of new data to assess the hydrocarbon potential of the Adavale, Cooper, and Eromanga Basins. The first of a series of about seven regional seismic reflection traverses has provided excellent data concerning the distribution of rock units and facies variations within these basins.

PETROLEUM SOURCE ROCK STUDIES

The maturity and petroleum source rock potential of the Eromanga Basin sequence was reported by Senior & Habermehl (1980)**. This work demonstrated that most of the Jurassic and some of the deeply buried Cretaceous rocks have generated hydrocarbons from relatively abundant source rocks. These studies were expanded during the year to evaluate critical sections within individual petroleum exploration wells. Drill cuttings were selected at 10 m intervals from Galway 1, Bodalla 1, and Durham Downs 1 and are being analysed by the 'rock eval' pyrolysis technique. Results are not yet available, but visual examination indicates good source rocks in the Thomson Syncline area owing to the presence of dark organic lutites in the Jurassic sequence in Galway 1.

HYDROGEOLOGY

A review of the hydrogeology of the Great Artesian Basin which encompasses the Eromanga Basin was published by Habermehl (1980)***. Research into the occurrence of naturally occurring isotopes, and hydrochemical investigations, are continuing. The objectives of this work are to determine flow velocities and flow directions within the multilayered confined aquifer system (Fig. S4). This information may have an important bearing on the migration and distribution of hydrocarbons within the Eromanga Basin sequence.

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* BMR Record 1980/32 (unpublished)

** BMR Journal of Australian Geology & Geophysics, 5(1), 47-55.

*** BMR Journal of Australian Geology & Geophysics, 5(1), 9-38.

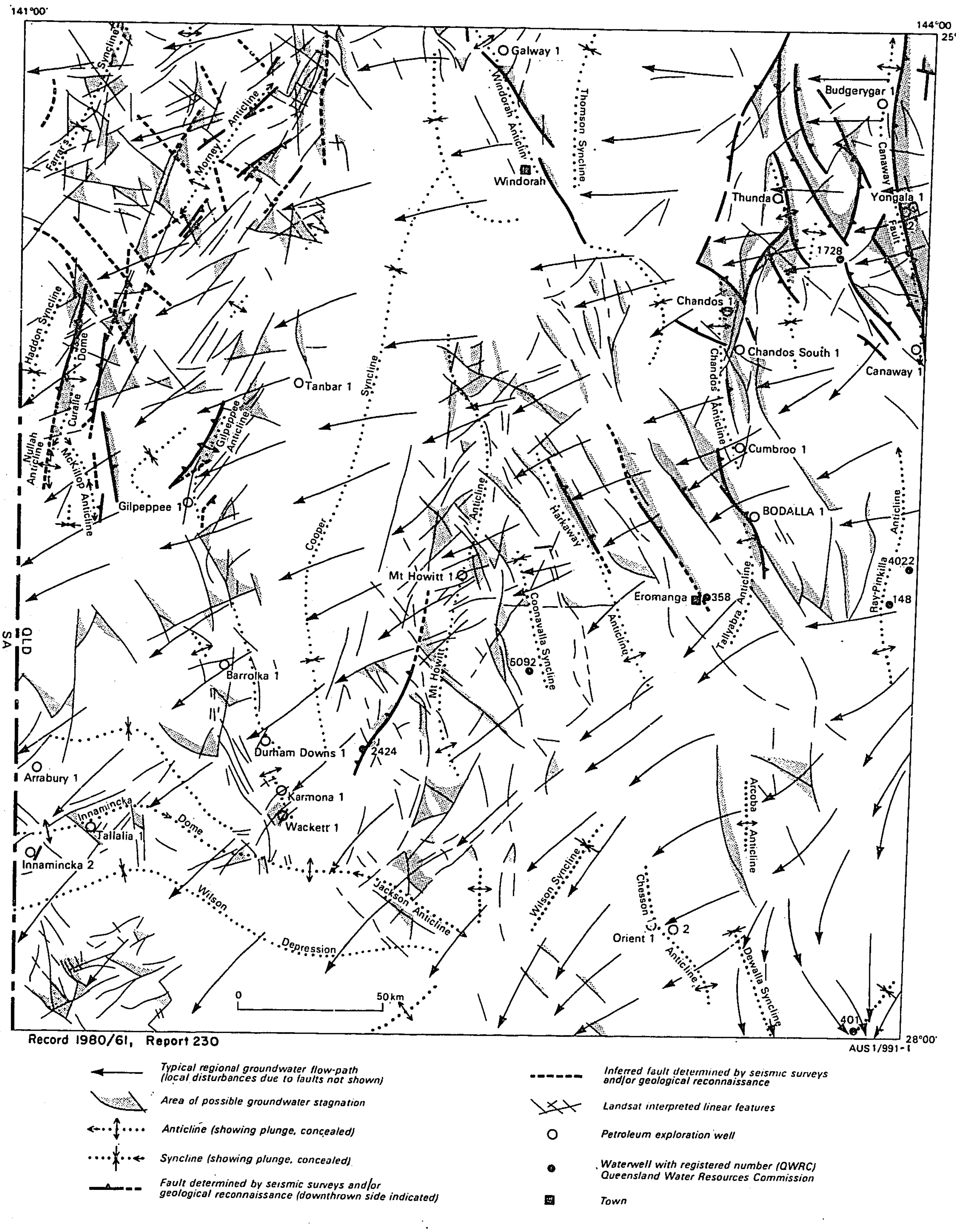

Fig. S4 Regional groundwater flow directions in aquifers in the central Eromanga Basin, geological structures and areas of possible groundwater stagnation.

As part of the hydrochemical study, forty-eight flowing artesian water wells on fourteen 1:250 000 map sheets located between 24° and 26°S and 140° and 145°E were sampled during a field trip in September 1980. All wells were sampled for chemical analysis and possible hydrocarbon content of the artesian groundwater; six selected wells were sampled with specially designed sampling tubes to obtain sealed throughflow grab samples, and 12 selected wells were sampled for environmental isotope analyses ($\delta^{13}C$), the analyses to be carried out by AAEC.

Results from the analyses of the samples taken might assist in the studies of possible hydrocarbon migration and stagnation within possible structural and stratigraphic traps in the area west of the Canaway Fault. These data can be expected to further define the hydrodynamic and hydrochemical character of this area.

AUSTRALIA-WIDE STUDIES

PERIOD STUDIES

by

W.J. Perry

STAFF: G.C.H. Chaproniere, W.J. Perry, M. Plane, B.R. Senior, S. Shafik, E.M. Truswell

The project began in 1979 as a pilot study of the Oligocene Epoch in Australia, with the aim of arriving at a satisfactory method of studying a geological period Australia-wide. Because the project is a part-time activity it has not yet reached the stage at which results can be reported; however, progress is as follows. A data base has been designed by the ADP Group, and coding forms have been standardised after some modifications to early drafts. Information from well completion reports has been entered into the data base for the Gippsland, Murray, and Bass Basins, and for the Arafura Sea area. Depths to top and base, and the thickness of Oligocene rocks, have been compiled for these regions, and an isopach map of Oligocene rocks in the Bass Basin, compiled at 1:500 000 scale, has been reduced to 1:2 500 000, the final map scale.

HYDROGEOLOGICAL STUDIES

MURRAY BASIN

by

C.M. Brown

STAFF: C.M. Brown, P.E. O'Brien, M.A. Habermehl (part-time), D.E. Johnstone, (Nov.-Dec. 79)

The objectives of the Murray Basin Hydrogeological Project are to collect, analyse, and interpret geological and hydrogeological data with a major aim of developing and applying a model which, if feasible, can be used to simulate the groundwater hydrodynamics of the Murray Basin as an aid to the management of its groundwater resources. The project is being undertaken jointly with the South Australian, Victorian, and New South Wales Geological Surveys and water authorities, and is co-ordinated by a steering committee comprising members of those organisations and BMR. The project is planned to last five years and has been organised into a number of phases. The first and current phase is a geological synthesis using all available geological and geophysical data.

During the year, work on the project in BMR was mainly concerned with data acquisition and with resolving problems associated with data transfer from State authorities to BMR. Borehole localities available to BMR were plotted on 1:250 000 transparencies, and downhole stratigraphic information was tabulated. A 1:1 000 000-scale base map was compiled using the 1:1 000 000 Aeronautical Charts, and the basin boundaries were derived from photoreductions of 1:1 000 000-scale geological maps. Further work was done on the compilation of a 1:1 000 000-scale geological map. Work was done to integrate reductions of the available 1:250 000 and 1:500 000 geological sheets and to solve map and State boundary problems. Compilation of a computerised bibliography of the Murray Basin was completed during the year. Digitally enhanced Landsat scenes were obtained from CSIRO, and a Landsat mosaic at 1:1 000 000 scale completed in October. Preliminary examination of the scenes covering the South Australia/ Victoria border area indicates that Landsat can be used to suggest alternative solutions to the problems of stratigraphic correlations across map sheet boundaries; e.g. the Quaternary Woorinen Formation (Vic.) is seen to overlie areas mapped as Pliocene Parilla Sand in the Naracoorte Sheet area (SA); the upper part of the Pliocene Parilla Sand, thought to be fluviatile in South Australia and to be shoreline deposits in Victoria, is seen to consist mainly of regressive beach/barrier bar ridges in both South Australia and Victoria, and to be contiguous with the Quaternary Bridgewater Formation at the coast in South Australia; the internal morphology of the Quaternary aeolian Lowan Sand (Vic.)/Molineaux Sand (SA) is characterised by westerly directed blow-out features, and therefore northwest-trending ridges mapped as Quaternary Lowan Sand in southwest Victoria can be correlated with northwest-trending Pliocene Parilla Sand ridges, which are probably flanked by local westerly trending small-scale blow-out deposits of Lowan Sand. Acquisition of data on the Devonian, Permian, and Cretaceous intrabasins underlying the Murray Basin continued throughout the year, and petroleum well locations were plotted on 1:250 000 and 1:100 000-scale base maps.

P.E. O'Brien joined BMR in July and commenced compiling the geology of the Early Permian marine sediments and Late Permian coal measures beneath the Murray Basin. Core and cuttings from the available petroleum wells were examined to improve the sedimentological understanding of the Permian rocks. Existing source and petrophysical data were also gathered in order to contribute to an assessment of the hydrocarbon prospectivity of the intrabasins.

E. Anderson, of the ADP Group, in collaboration with M.A. Habermehl, designed a data base system for handling hydrogeological data on the BMR Hewlett Packard computer.

In South Australia, D.R. Edwards, J.A. Reed, and S.R. Barnett issued three hydrogeological reports which contribute to the Murray Basin Project as part of an on-going hydrogeological assessment of the western Murray Basin being undertaken by the South Australian Department of Mines and Energy. In Victoria reports on the subsurface geology and hydrogeology of the Shepparton area, by S.J. Tickell and W.E. Humphrys, were issued by the Geological Survey of Victoria. In New South Wales the Water Resources Commission continued exploratory drilling and assessment of the eastern Riverine plain and Ovens Graben areas.

GREAT ARTESIAN BASIN

by

M.A. Habermehl

STAFF: M.A. Habermehl; G.E. Seidel (until 15 February)

The Great Artesian Basin Project consists of a hydrogeological study of the multi-aquifer confined groundwater basin, and the development and application of a mathematical, computer-based model to simulate the groundwater hydrodynamics. The study started in 1971 and a model (GABHYD) was prepared from 1975 to 1977. Calibration was carried out during 1977 and 1978, and application runs were made in 1978. The simulation model's predictions of the future hydraulic behaviour of the basin following management interventions can be used on a regional scale for assessment, planning, and management purposes of the basin's artesian groundwater resources.

During 1980, documentation of the hydrogeology of the Great Artesian Basin and of the GABHYD computer programs and operating systems continued. The papers 'The Great Artesian Basin, Australia' by Habermehl, and 'Application of the GABHYD groundwater model of the Great Artesian Basin' by Seidel, were published in the BMR Journal. These papers describe the results of the hydrogeological study of the use of the computer model.

A related paper 'Structure, hydrodynamics and hydrocarbon potential, central Eromanga Basin, Queensland, Australia' by Senior & Habermehl was also published in the BMR Journal.

During the year GABHYD data was made available to the Geological Survey of South Australia and private groundwater consultants for studies of proposed new developments in the basin. Documentation of the GABHYD model was completed with Record 1980/22 - 'The model algorithm for the GABHYD model of the Great Artesian Basin' by Seidel - before Seidel left BMR on 15 February 1980 for a two-year secondment to the Geological Survey of Papua New Guinea.

Documentation of some aspects of the hydrogeology were reported in more detail by Habermehl in the Reports - 'Investigations of the geology and hydrology of the Great Artesian Basin, 1878-1980' and - 'Springs in the Great Artesian Basin, Australia - their origin and nature'. The first of these describes the investigations of the geology and hydrology of the Great Artesian Basin between 1878 and 1980 and contains an extensive bibliography. The other Report describes and lists about 600 springs located in eleven groups in the Great Artesian Basin; hydrogeological characteristics, possible origins, discharges, and aspects of physical and chemical characteristics are described.

A poster-display on the Great Artesian Basin was prepared for the International Association of Hydrological Sciences Symposium on - 'The hydrology of areas of low precipitation', from 10 to 13 December 1979 at the 17th General Assembly of the International Union of Geodesy and Geophysics at Canberra, and for use in the BMR foyer.

During a field trip in the central part of the Great Artesian Basin (as part of the Central Eromanga Basin Project) from 18 September to 1 October 1980, Habermehl sampled 48 flowing artesian water wells on 14 1:250 000 map sheets located between 24° and 26°S, and 140° and 145°E. Groundwater samples were collected for chemical analysis and possible hydrocarbon content; six selected wells were sampled with specially designed sampling tubes to obtain grab samples, and 12 selected wells were sampled for isotope analyses ($\delta^{13}C$), to be carried out by AAEC. Results of this study could lead to further research and/or methods to aid hydrocarbon exploration, and to define the hydrodynamic and hydrochemical character of possible hydrocarbon occurrences as outlined in the paper by Senior & Habermehl (1980; see second footnote on p. 12).

A report was prepared for the 17th Meeting of AWRC-TCUW in Melbourne in March 1980 on proposals for study of recharge and hydrochemistry in the Great Artesian Basin. It was stated that BMR is not in a position to undertake a study of recharge to the Great Artesian Basin, which would be a complex and major project, requiring considerable co-operation and effort by several Federal and State organisations. A large number of chemical data is available from wells in the Great Artesian Basin, but no basin-wide study of the hydrochemistry has been carried out; BMR has initiated a pilot study of the hydrochemistry on existing results of chemical analyses from water samples of selected water wells. A bibliography on the Great Artesian Basin was prepared for presentation at the TCUW meeting.

WIRE-LINE LOGGING OF WATER WELLS IN THE GREAT ARTESIAN BASIN

by

M.A. Habermehl

STAFF: M.A. Habermehl, J.A. Morrissey

The objective of the well logging program is to geophysically log existing water wells in the Great Artesian Basin to obtain information on the subsurface geology and hydrogeology.

Data from about 1250 flowing and non-flowing artesian water wells and some converted petroleum exploration wells in Queensland, New South Wales, and the Northern Territory which were logged by BMR and its contractors from 1960 to 1975 were transcribed onto transfer sheets, punched on cards, and stored on magnetic tape. Basic well and log data of water wells logged by the Geological Survey of New South Wales (about 235) and South Australia (17) in their parts of the Great Artesian Basin were also recorded.

The results of chemical analysis of water samples from part of the wells logged, and the barometric data used to determine the elevations of well sites, were added to the data base. Drillers' logs were added to the wire-line logs. Overlays showing well locations and some log data were prepared for all 1:250 000 map sheets on which logged wells occur, and well locations were checked and transferred to a map at 1:2 500 000 scale.

Master copies of paper prints of all logs at 1 inch: 100 feet scale were maintained, as well as the original transparencies of the logs produced by BMR, which are used to produce copies of logs requested by visitors, industry, and State authorities. Copies of the magnetic tape containing well and log data were produced during the year at the request of companies.

The organisation of the well and log data was documented in Record 1980/9 - 'Wire-line logging of waterwells in the Great Artesian Basin - ADP data transcription manual' by Habermehl. The listing of all well and log data from the wells logged is given in the Report 'Index of geophysical well logs acquired by BMR from water wells in the Great Artesian Basin, 1960-1975' by Habermehl & Morrissey. Completion of the listing of the computer-stored data is awaiting some programming and processing by the ADP Section. The map at scale 1:2 500 000, which contains the locations of the wells logged and which will accompany the index listing, was completed.

ISOTOPE HYDROLOGY OF THE GREAT ARTESIAN BASIN

by

M.A. Habermehl

STAFF: M.A. Habermehl

Naturally occurring isotopes in the artesian groundwater of the main Jurassic/Early Cretaceous aquifers of the Great Artesian Basin are being studied by officers of the Nuclear Hydrology Group of the Isotope Division of the Australian Atomic Energy Commission in collaboration with BMR.

Objectives of the study are to provide information complementary to data obtained by conventional hydrological techniques, and to provide an independent check on derived hydraulic data. The residence time and the rate of flow of the groundwater through the aquifers can be estimated and its origin elucidated. In addition, valuable information on the chemistry of the groundwater and the aquifers, and on the possible transport by groundwater of minerals and hydrocarbons, is obtained.

Water samples from artesian wells are analysed where appropriate for the environmental isotopes D, C^{13}, C^{14}, O^{18}, Cl^{36}, Ra^{226}, and U^{234}. and detailed chemistry. The wells sampled were selected by Habermehl on hydrogeological criteria and location through the basin.

During 1974 and 1975, Dr G.E. Calf (AAEC) collected samples from 82 flowing and non-flowing artesian wells in the northeastern, east-central, and south-central parts of the basin; most of the wells are located along flowlines of the artesian groundwater in the main Jurassic/Early Cretaceous aquifers, in a pattern radiating outwards from the recharge areas. During 1976 a joint party (Calf and Smith, AAEC; Habermehl, BMR) sampled 24 flowing artesian water wells and mound springs in the southwestern part of the basin; during 1978 a combined party (Calf and Seatonberry, AAEC; Habermehl, BMR) sampled 30 flowing artesian water wells in the southeastern part of the basin; and during 1979 a joint party (Calf and Smith, AAEC; Habermehl, BMR) sampled 26 flowing artesian water wells in the northwestern part of the basin. During a field trip in the central part of the basin in September 1980, Habermehl sampled 10 selected flowing artesian water wells for environmental isotope analyses ($\delta^{13}C$).

Results from analysis of samples collected in the eastern areas of the basin show that the artesian water is of meteoric origin. Analyses of hydrogeological, hydrochemical, and isotope ratios show that highly compatible results are obtained. Groundwater movements in the main aquifer in the Lower Cretaceous/Jurassic sequence have average velocities ranging from about 1 to 5m/year. Chloride, sodium, and bicarbonate ions, when plotted against age, all show similar regular curves. A general correlation exists between chloride levels and mean annual rainfall during the last 120 000 years. Some interpretations of early results were published in a joint AAEC-BMR paper 'Aspects of the isotope hydrology of the Great Artesian Basin, Australia' by Airey & others (1979)*. As much of the groundwater in the basin is very old, it severely restricts the application of ^{14}C dating. Techniques are being developed to extend the dating beyond the limits of carbon 14 (30 000 to 40 000 years); application of the long-lived isotope of ^{36}Cl (half life - 308 000 years) would be more suitable for the dating of very old groundwater in the Great Artesian Basin. Steps were undertaken during the year to initiate a collaborative study of the distribution of ^{36}Cl and noble gases throughout the basin by the University of Arizona, AAEC, BMR, and ANU.

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*In ISOTOPE HYDROLOGY 1978, 1, 205-19. IAEA, Vienna.

PHOTOGEOLOGY AND REMOTE SENSING

by

C.J. Simpson

STAFF: C.J. Simpson, W.J. Perry (part-time), M. Fetherston (part-time)

BMR FIELD RESEARCH

GEORGINA BASIN PROJECT

Photo-interpretation of the contact between the basement and the Georgina Basin sequence in the Huckitta 1:250 000 Sheet area, followed by a two-week field visit, led to the proposal of a structural model similar to that developed in the Hay River area, namely of north-moving fault blocks with thrusts on their leading edges.

REMOTE SENSING (Landsat)

The study of Toolebuc Formation outcrop in Queensland using Landsat colour composite images indicated that the satellite data may be useful for outlining the regional distribution of the unit. The visual assessment was followed by digital analysis of tape data from a small test area using the CSIRO Division of Computing Research facilities. This latter work gave encouraging results but the technique has yet to be tested regionally.

A study of Landsat imagery to detect lineaments was made of an area on the Manara 1:250 000 Sheet around a proposed drill site for the Devonian Source Rock Project. Northwesterly trending lineaments near faults shown by previous seismic surveys were taken into account during final selection of the drill site.

Collaborative work with field geologist I. Crick on computer-processing of Landsat tape data from the Litchfield Complex, NT, using the CSIRO Division of Mineral Physics analysis system at North Ryde, resulted in reasonably successful discrimination of granitic outcrops from other rock types such as metamorphics. Further work in this region is programmed. A similar study in the McArthur Basin, with the objective of detecting and mapping the distribution of volcanics using Landsat data, was unsuccessful.

TRAINING

In November Simpson gave lectures on 'Landsat interpretation for hydrology' and 'Side-looking radar' to the Australian Water Resources Council remote sensing workshop held in Canberra.

During February he conducted two one-week photogeology courses in Bandung to sixteen Geological Survey of Indonesia geologists, nine of whom belonged to the Irian Jaya Geological Mapping Project. The courses were arranged at the request of the Project Leader of the Irian Jaya Geological Mapping Project.

Simpson supervised a study by M. Fetherston of lineaments in the Emu Fault area-McArthur River (NT) during Fetherston's secondment to the section for one month. The study attempted to better define the position of the Emu Fault in extensive alluvial cover between McArthur River and the coast. Evaluation is still in progress. Simpson also gave a week-long in-house course in photogeology to a staff member recently returned to Canberra from Papua New Guinea.

For the Australian Mineral Foundation (AMF), Perry and Simpson revised notes from previous AMF courses 'Photo-interpretation for survey & exploration geologists' (1979), and 'Geological interpretation of Landsat imagery' (1978), and together with notes from Dr. J.F. Huntington, CSIRO, combined them into a new manual for an AMF course scheduled for December 1980, 'Geological interpretation of air photographs and satellite images'.

MARINE GEOLOGY AND COASTAL STUDIES

GREAT BARRIER REEF STUDIES

by

J.F. Marshall

STAFF: P.J. Davies, J.F. Marshall, B.M. Radke, K.A. Heighway, B.G. West, D. Foulstone, T. Dalziell (part-time).

CENTRAL GREAT BARRIER REEF

1980 saw a change in locale for reef studies with the commencement of fieldwork in the central Great Barrier Reef area, off Townsville, after four years of concerted research in the southern Great Barrier Reef. The research plan is to study a number of selected reefs in both the central and northern regions of the Great Barrier Reef over the next three years, to test the models and hypotheses developed from work in the south. This broader approach should allow for a more meaningful interpretation of reef growth for the province as a whole, and allow such factors as latitudinal variation and different physiographic, tectonic and hydrologic conditions to be assessed. Allocation of AMSTAC/FAP funds ($30,000 for 1979/80 and $50,000 for 1980/81) has enabled the program to proceed on schedule.

Fieldwork in April/May and September/October has been concentrated on some of the reefs off Townsville (Wheeler, Viper, Stanley) in co-operation with the Geography Department, James Cook University. Field techniques employed have been shallow seismic refraction, sediment sampling and water monitoring, mapping of reef surface features, and shallow augering.

REEF GROWTH - SOUTHERN GREAT BARRIER REEF

The biologic accretion of calcium carbonate during the Holocene has resulted in relatively thin (3-23 m) developments of reef. Coring of the reef has shown the large variation in the type of framework produced and the rate at which it accreted. At One Tree Reef growth on the windward margin is dominated by head corals together with a coralline algal/*Millepora*/vermetid assemblage that forms a massive framework. At the junction of the reef flat with the sand wedge, loose sandy sediments were encountered to a depth of 11 m. At leeward sites branching corals dominate, and form an open framework.

Radiocarbon dating of core material has shown that growth rates have varied from 0.6 to 8.3 m per thousand years. At One Tree Reef the windward margin reached sea level around 5000 years B.P.(DH2, Fig. S5) whereas parts of the leeward margin did not reach sea level until about 1000 years B.P. (DH3, Fig. S5). Much of the sand section in DH1 did not begin to accumulate until the windward margin had reached sea level, which suggests that little material is shed during the vertical growth phase.

SUBMARINE LITHIFICATION

Windward reef slopes in the southern Great Barrier Reef have been shown to be suitable sites for extensive submarine lithification. Both crystalline (aragonite and bladed high-Mg calcite spar) and microcrystalline (micrite and peloids) cements occur within the reef framework. These cements are considered to be contemporaneous with reef growth and have developed in an environment characterised by slow accretion rates. Aragonite cements within the pores of

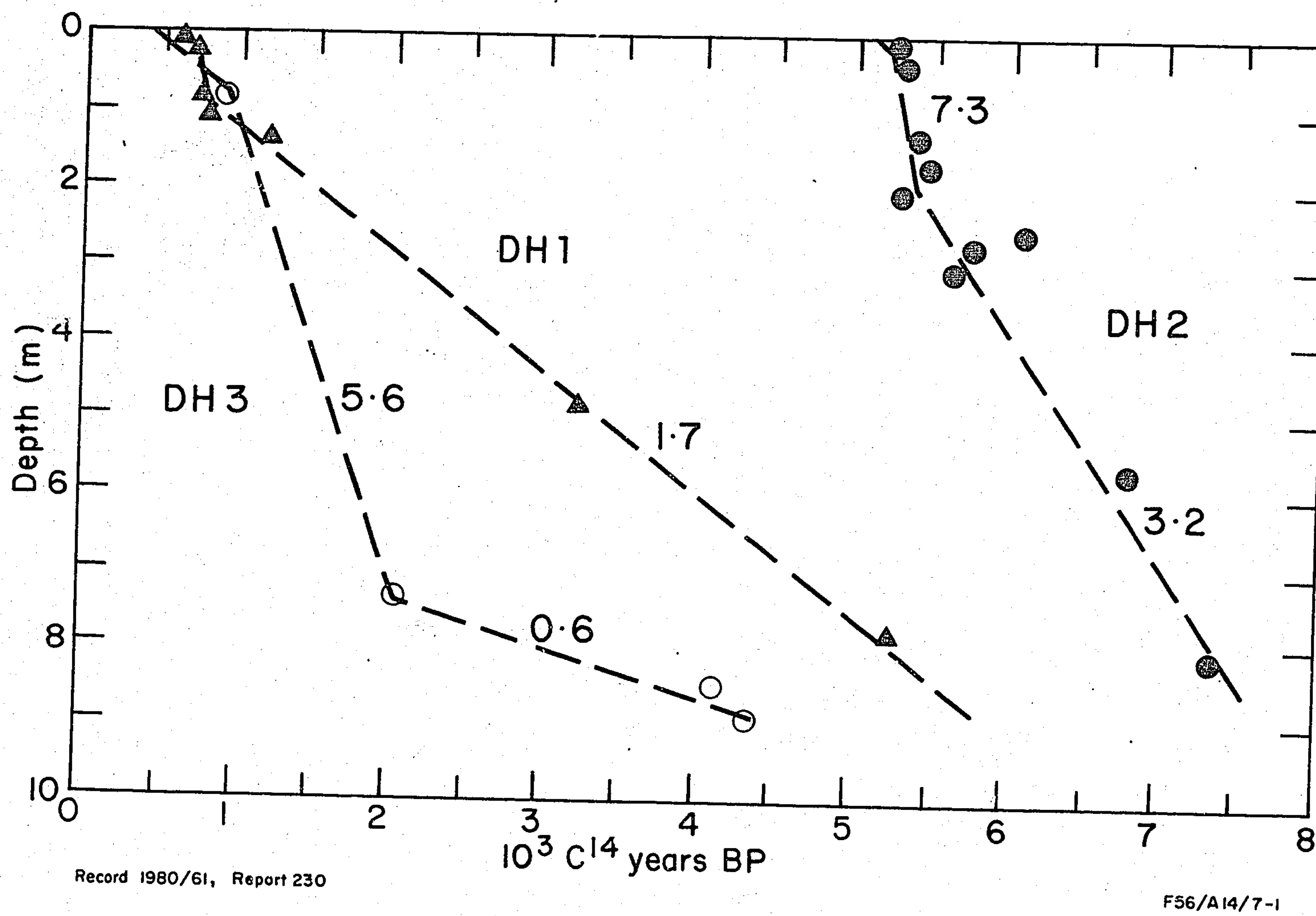

Fig. S5 Rates of reef accretion (m/kyr) displayed in three boreholes at One Tree Reef. Note that accretion in hole I starts only after the perimeter margin (hole 2) has reached sea level around 5000 yr BP. Only corals in growth position have been dated.

corals appear to be localised by the coral structure, and the growth of high-Mg calcite micrite both on the aragonite cement and coral walls inhibits further nucleation of aragonite, but is conducive to the eventual growth of bladed high-Mg calcite spar. This suggests that changes in cement mineralogy are affected by processes which control the formation of high-Mg calcite micrite, and that these largely unknown processes relate to the dominance of high-Mg calcite as a submarine cement.

EXMOUTH AND WALLABY PLATEAUS GEOLOGICAL STUDIES

by

N.F. Exon, J.B. Colwell

Analysis, evaluation, and reporting of results of the 1979 Sonne cruise over the Exmouth and Wallaby Plateaus off northwestern Australia were completed in association with scientists from the Bundesanstalt fur Geowissenschaften und Rohstoffe (Hannover, West Germany). The main aims of the cruise were to sample pre-Quaternary sediments on the margins of the plateaus, to determine the nature of Quaternary sedimentation in the region, and to obtain Quaternary cores for gas analysis. Initial results were given in last year's Summary of Activities.

Four papers were completed during the year by various authors: 'Geology of the Exmouth and Wallaby Plateaus, off northwest Australia: sampling of seismic sequences', 'Geological development of the passive margins of the Exmouth Plateau off northwest Australia', 'Sedimentological studies of Cainozoic sediments from the Exmouth and Wallaby Plateaus', and 'The petrography of some rocks from the Exmouth, Wallaby and Scott Plateaus'. The results of the work in the region have led to considerable changes in the understanding of the development of the northern margin of the Exmouth Plateau, which behaved more as part of the offshore Canning Basin than of the Carnarvon Basin. A minimum mid-Cretaceous age (K/Ar age: 89 m.y.) was determined for a partly altered basalt from the southern Wallaby Plateau. This suggests that intense volcanism and associated deposition of volcaniclastic debris flows formed the plateau during or after the Neocomian break-up of this region. Therefore the plateau appears to have no petroleum potential. Quaternary cores in the central Exmouth Plateau contain very small amounts of methane; the $\delta^{13}C$ isotope results (-14 to -40 parts per thousand) and the absence of higher hydrocarbons tend to downgrade the petroleum potential of this part of the plateau, a feature largely confirmed by subsequent company drilling.

TASMANIAN AREA MARINE GEOLOGY

by

H.A. Jones

A 1:1 million map of the surface sediments of Bass Strait and the Tasmanian shelf was printed during the year. Interpretation of the sedimentological data was still in progress at the end of the period under review. Pollen analyses from muddy sediments of the middle shelf off eastern Tasmania are being carried out by Dr Macphail at the University of Tasmania, and the results of this work could have important implications for the interpretation of depositional processes in this area.

MANGANESE NODULES IN THE AUSTRALIAN REGION - A REVIEW

by

H.A. Jones

A compilation and assessment of available data on deep-sea manganese nodules in the Australian region was carried out. Dense concentrations of nodules are known to exist southwest of the continent (the Cape Leeuwin field), and south of Tasmania, and scattered occurrences have been recorded in the Tasman Sea and eastern Indian Ocean. On existing data, only the Cape Leeuwin field has any resource potential: here nodules are distributed over an area of at least 1 000 000 km^2; concentrations are apparently quite dense; and Ni values commonly exceed 1 percent. Part of the field is less than 1000 km from the industrial centres of southwestern Australia. On the debit side, the field lies in relatively high latitudes and is therefore exposed to frequent severe weather and sea conditions; more important, the Ni, Cu, and Mn contents of the nodules are significantly below the currently accepted economic cut-off grades. As yet samples from the field are few in number and widely spaced, and large areas of higher grade nodules may still be discovered. If however, the values obtained from the small number of available analyses are representative of the whole field, the potential for establishing a mine site in the area in competition with higher-grade deposits of the eastern Pacific would appear to be remote.

Elsewhere in the Australian region the density of sampling of the deep sea floor is too sparse to allow any general conclusions to be drawn. On the basis of the well-established relationship between the high-grade nodule fields of the north-equatorial eastern Pacific and the equatorial siliceous ooze belt, the obvious target for future exploration is the corresponding equatorial siliceous ooze belt of the eastern Indian Ocean. No analyses are available from the siliceous ooze belt itself, and the handful of analyses from this general region are not particularly encouraging, although a Cu value exceeding 1 percent was recorded southeast of the Cocos Islands during the Dodo expedition. However, the region is very poorly known, and additional sampling is badly needed. In the Pacific there appears to be a relation between the grade and abundance of nodules and the age of the underlying oceanic crust; higher-grade nodules occur on crust formed in the mid-Tertiary. If this relation has general validity, the potential of the eastern Indian Ocean siliceous ooze belt is downgraded because the crust there is of Mesozoic age.

MANGANESE NODULE SAMPLING IN CAPE LEEUWIN FIELD

by

J.B. Colwell

During November 1979, manganese nodules were sampled during a cruise of HMAS Moresby southwest of Perth. Seven stations were occupied, six successfully, and 215 nodules were recovered. Chemical analyses on representative nodules produced an average Ni + Co + Cu value of 1.57% which is similar to previously published average values for the Cape Leeuwin field. These values are well below the levels likely to be of immediate economic interest.

OFFSHORE HEAVY-MINERAL SAND STUDIES

STAFF: H.A. Jones, J.B. Colwell, M. Tratt, L. Pain

In September a study was commenced, in co-operation with the Federal Republic of Germany, to investigate the superficial deposits on the continental shelves off northern New South Wales and southern Queensland, in order to determine a stratigraphic framework for locating possible offshore accumulations of heavy minerals. Both State Geological Survey and BMR scientists and technicians participated in the work aboard the research vessel Sonne, which is mainly staffed by personnel from the Bundesanstalt fur Geowissenschaften und Rohstoffe, Hannover. The cruise was arranged under the Federal Republic of Germany-Australia Science Agreement. Work commenced on the New South Wales shelf and comprised seismic reflection profiling, dredging, and coring.

PALAEONTOLOGICAL STUDIES

Activities are reported below under the names of the authors. Locations of projects are shown in Figure S6.

D.J. BELFORD (assistants F. Hadzel, P.W. Davis)

Belford was attached to the Natural Resources Division, ESCAP, Bangkok, until December 28, 1979, as co-ordinator of IGCP Project No. 32 "Stratigraphic correlation of sedimentary basins in the ESCAP region". Final proofs of Mineral Resources Development Series Volume No. 45, containing the proceedings of the Third Working Group Meeting held in November, 1978, were returned to the printer. The manuscript of MRDS Volume No. 46, which is the second volume of the Atlas of Stratigraphy, was forwarded to the printer; this volume contains contributions describing eight Australian Basins and a complete contribution from Japan. The first proof was corrected and returned.

Several papers describing sedimentary basins of the western Himalayas were received and edited for a proposed Atlas of Stratigraphy volume describing basins from India, Bangladesh, Nepal, and Tadjikistan. Another proposed Atlas volume could contain contributions from Australia, Indonesia, the Solomon Islands, Fiji, and possibly New Zealand.

Three sheets of the sedimentary basins map were distributed and two sheets submitted for printing. An annual report on the project was prepared for the IGCP Board. No progress has been made with the project since the end of 1979, because of the lack of a co-ordinator in Bangkok.

Belford resumed duty at BMR on March 11. Study of foraminifera from the Blucher Range and Wabag 1:250 000 Sheet areas, Papua New Guinea, continued. A draft manuscript has been completed, and compilation of plates, sample locality maps, tables, and text-figures is in progress. The sediments range in age from early Paleocene to Pliocene; some new planktic species and subspecies have been described.

Adding of data to the palaeontological retrieval system has continued. Considerable progress has been made with the type foraminiferal collection and the general Western Australian collection. It is intended to prepare catalogues when data entry is completed.

1 Oligocene and Miocene larger and planktonic foraminifera
2 Palaeozoic conodonts, Carnarvon Basin
3 Archaean stromatolites and microfossils
4 Early Proterozoic microfossils and stromatolites
5 Early Proterozoic microfossils
6 Late Cretaceous foraminifera, Scott Plateau
7 Lower Carboniferous conodonts, Bonaparte Gulf Basin
8 Late Cambrian trilobites, Bonaparte Gulf Basin
9 Lower Carboniferous and Upper Devonian ostracods from the Bonaparte Gulf Basin
10 Lower Carboniferous and Upper Devonian ostracods, Canning Basin
Upper Devonian conodonts from the Canning Basin
Upper Devonian and Lower Carboniferous fishes from the Canning Basin
11 Permian invertebrate faunas
12 Upper Palaeozoic and Mesozoic plants
13 Cretaceous marine molluscs from northern Australia
14 Tertiary mammals from N.T., Qld and S.A.
15 Agnostid trilobites from N.T. and N.S.W.
Middle Cambrian trilobites of northern Australia
16 Tertiary pollen, central Australia
17 Late Cambrian and early Ordovician rostroconchs; early Ordovician pelecypods
18 Biostratigraphy of Devonian vertebrates in Amadeus and Georgina Basins
19 Late Cambrian and early Ordovician trilobites and conodonts, Georgina Basin
20 Silicification of modern algae
21 Upper Mesozoic pollen, spores, microplankton and macrofaunas from the Carpentaria Basin
22 Middle/Late Devonian fishes, Broken R/Gilberton area
23 Tertiary planktic foraminiferids, Coral Sea
24 Tertiary nannofossils Coral Sea Basin. Oligocene — Miocene larger foraminifera
25 Permian spores and pollen, Galilee Basin
26 Permian faunas and time relationships, Sydney Basin
27 Silurian conodonts, Canberra region
Silurian brachiopods of the Canberra region
28 Devonian fishes from eastern Australia
29 Miocene larger and planktonic foraminifera
30 Permo-Carboniferous spores and pollen, Tasmania
31 Tertiary foraminifera, PNG
32 Mesozoic marine molluscs from PNG
33 Tertiary land mammals
34 NERDDC Oil Shale Methodology Project (palynology)
35 Upper Cretaceous nannofossil biostratigraphy

East Australian Permian coal basins (NERDDC Project)

SOUTHWEST PACIFIC
Lower Cretaceous — Quaternary nannofossil biostratigraphy

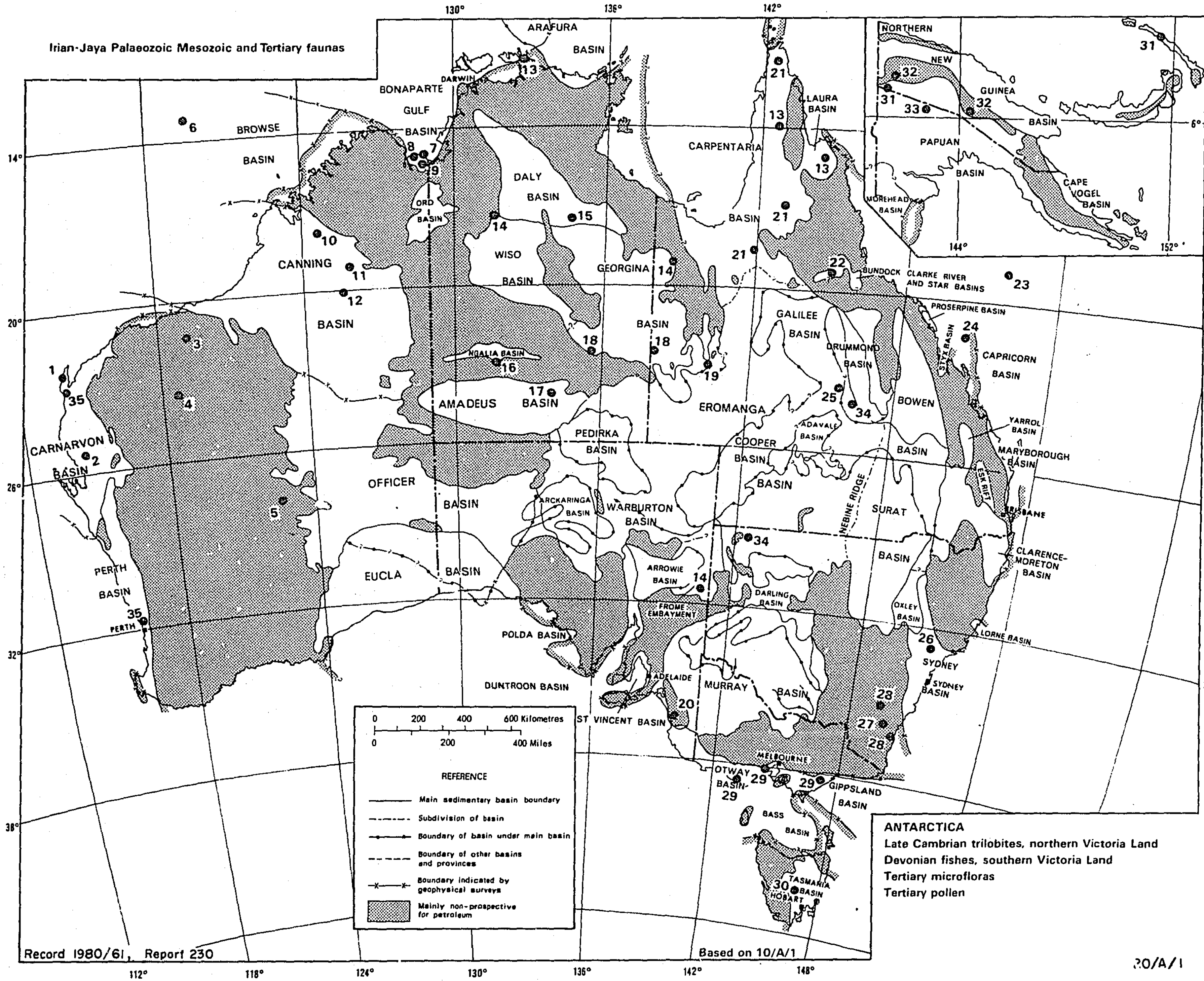

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Fig. S6 Current palaeontological projects

D. BURGER (assistant L.J. Kraciuk)

Biostratigraphic and palaeoenvironmental basin studies

A paper is being prepared, together with N.F. Exon, on Jurassic and Cretaceous cyclic sedimentation in the Surat Basin. Palaeontological and palynological age determinations of repeated sedimentation patterns mapped in the basin suggest that this cyclicity may be tied to global eustatic sea level movements in the Mesozoic.

A study of spores, pollen grains, dinoflagellates, and acritarchs from the basal Cretaceous Gilbert River Formation of the Carpentaria Basin is now completed. This study presents new evidence for the age of the formation, and this evidence can be used to date the non-marine correlative sediments elsewhere in the Great Artesian Basin (Hooray Sandstone, Cadna-owie Formation, Mooga Sandstone, Bungil Formation). A study of the Wallumbilla and Toolebuc Formations is now completed and will be written for publication shortly.

Macrofossils were collected from the Gilbert River Formation in the southern Carpentaria Basin. Study of these collections by S.K. Skwarko is expected to: a) give a better idea of the position of the Neocomian-Aptian boundary in the basin, and b) provide evidence which might verify and complement palynological data regarding the age and palaeoenvironments of the Gilbert River Formation.

Detailed palynological work on drill-stem cores of the Toolebuc Formation and its correlative intervals started in June, as a contribution to the NERDDC oil shale project. The first borehole (BMR Urisino 1, NSW) penetrated a sequence similar to the Albian stratigraphy in northern South Australia. It was proven that gamma-ray anomalies found in New South Wales are not connected in time with the well-known Toolebuc anomaly in Queensland. Also, a better definition of the *Phimopollenites pannosus* zone enabled an accurate correlation to be made with the Oodnadatta Formation in South Australia, confirming the lithological correlation.

Coal exploration in northern Queensland

Utah Development Co. conducted a drilling project in search of coal in the Olive River and Wenlock River areas in northern Cape York Peninsula. At the company's request samples from Carboniferous, Permian, and Jurassic sediments were analysed for palynological age determination of potentially coal-bearing strata.

International conferences

A paper entitled 'Albian angiosperm distribution and habitat in Queensland, Australia' was submitted as a contribution to the Fifth International Palynological Conference Topic 17 - Angiosperm origins. It presented the latest evidence regarding biostratigraphy and palaeoenvironments interpreted from the pollen record, and this evidence conforms with modern concepts propounded by palaeobotanists from the USA, Europe, and the USSR on the rise and global migration of the oldest-known angiosperms.

An abstract entitled 'Early Cretaceous stratigraphic palynology in eastern Australia' was submitted as a contribution to the Twenty-sixth International Geological Congress Symposium S.04.3.1 - Palynostratigraphy. This abstract reviews the possibilities of palynological correlation of marine and non-marine sedimentary sequences in eastern Australian basins, and the use of palynology in reconstructing palaeoenvironments and palaeoclimates.

Geological cruise on R/V Sonne

Palynological studies were made on dredge samples from the Exmouth Plateau (Indian Ocean, lat. 20°S, long. 113°E), which were collected by R/V Sonne in January and February 1979, under the auspices of the Federal Republic of Germany/Australia Science Agreement. Some of the samples from the Upper Jurassic and Lower Cretaceous sequence yielded palynomorphs, and hence could be dated, but no fossils were recovered from any of the numerous samples from the Upper Cretaceous and Tertiary sequence.

Collections

Maintaining and extending several collections of fossil types and slides (CPC, ESCAP, study) is a continuing activity. The present palynological study collection includes 15 000 permanent microscope preparations.

Bibliography

In view of the rapidly expanding systematic literature on fossil dinoflagellates, a system of edge-punch cards for data storage and retrieval of fossil dinoflagellate genera of the world was set up in 1973. It is continually brought up to date and at present includes over 320 genera.

The BMR Index of Fossil Palynomorphs now includes over 1500 species of spores, pollen grains, dinoflagellates, and acritarchs.

G.C. CHAPRONIERE(assistants F. Hadzel, P.W. Davis)

The study of larger foraminiferids from the early Miocene of Victoria continued throughout the year; all samples collected during the 1977 field season, except those from the Hamilton area, have been picked. A number of specimens of Austrotrillina howchini have been found from a number of localities, including some where it has not been previously recorded. An important find has come from Clifton Bank, Muddy Creek (Hamilton); the species was described from Muddy Creek, but the level at which it had been found had not been located until now. This locality is almost certainly very close to the type, and as the type specimens appear to have been lost, the find is significant.

A new project was commenced this year: a detailed study of wall textures in mid-Tertiary Globigerina and Globigerinoides. Work so far suggests that changes in wall texture appear to be controlled by temperature and water depth. Even so, it appears that Globigerina woodi is a shallow-water derivative of G. praebulloides, and that G. woodi gave rise to Globigerinoides in southeastern Australia. The study has also permitted a closer correlation between the warm-water and cool-water planktic foraminiferal zonal schemes. This project will continue through 1981.

Palaeontological work for the Irian Jaya Geological Mapping Project and the Papua New Guinea Geological Survey was undertaken as necessary.

Data have also been added to the palaeontological retrieval system.

J.M. DICKINS (assistants H.M. Doyle and R.W. Brown)

Dickins attended the 5th Gondwana Symposium in Wellington, New Zealand, in February, where he delivered a joint paper prepared with S.C. Shah, of the Geological Survey of India, on the Permian palaeogeography of Peninsular and Himalayan India. This paper will be published in the proceedings of the Symposium. He participated in two field visits to examine upper Palaeozoic and lower Mesozoic sequences of New Zealand. At the meeting of the Gondwana Subcommission held during the Symposium he was reappointed Chairman of the Subcommission. The next Symposium is to be held at the Polar Research Institute, Ohio State University, Columbus, USA, in 1984.

He made changes to the manuscript on the Permian invertebrate fauna from the Warwick area, Queensland, after editing, for publication in a BMR Bulletin of Palaeontological Papers.

He was on leave from May to August, during which he to attended in Beijing a Symposium on Tibet at the invitation of the Academia Sinica, visited Tibet, and attended (on duty) the International Geological Congress in Paris in July. Before the Symposium on Tibet he visited the Institute of Geology and Palaeontology of the Academia Sinica in Nanjing, where he examined late Palaeozoic faunas from China and Tibet and had discussions with colleagues about the faunal relations and correlations. The Symposium on Tibet was followed by a geological field visit to Tibet. After travelling from Lhasa to Kathmandu he spent a few days in Nepal and a week in India making contact with the geological organisations there.

He then travelled to London and worked at the British Museum (Natural History) on the morphology, systematics and evolutionary changes in some late Palaeozoic bivalves. This work has applications in understanding the upper Palaeozoic sequences in Australia and Irian Jaya. From London he travelled to Paris to attend the International Geological Congress and to visit the Carnic Alps of southern Austria and northern Italy.

In Paris he was the organiser of the meeting of the IUGS Subcommission on Permian Stratigraphy, and attended the meeting of the Commission on Stratigraphy, of which he is a member. He was also an observer at the meeting of the Subcommission on Triassic Stratigraphy. He gave a paper at the Tethyan Symposium of IGC on palaeogeographic relationships during the late Palaeozoic in the eastern Tethys.

In the Carnic Alps he examined Permian and Triassic sequences as part of working group activities of the Permian Subcommission. Some recommendations about stratotypes for the Permian time scale are following.

J. GILBERT-TOMLINSON (assistant H.M. Doyle)

Joyce Gilbert-Tomlinson retired in July following 43 years working on early Palaeozoic faunas. Her most recent project was a study of Western Australian trace fossils.

P.J. JONES (assistant A.T. Wilson)

Research efforts have been concentrated on the completion of papers on Cambrian bradoriids and Devonian thelodont scales and ostracods from the Georgina Basin, and to a lesser extent, on investigations of Late Devonian and Early Carboniferous ostracods from the Bonaparte Gulf and Canning Basins. The ultimate objectives of these endeavours are to determine the taxa that belong to these fossil groups, their ages, and their ecological significance as aids to correlation.

Phosphatic bradoriids have been described from the Middle Cambrian of the Georgina Basin, in collaboration with Dr K.G. McKenzie (Riverina CAE). New taxa have been proposed and the palaeobiogeography and biological affinities of the Bradoriida have been discussed in Alcheringa. Zepaera Fleming, 1973, is revised, and Flemingia gen. nov. is described from the late Templetonian Monastery Creek Phosphorite Member of the Beetle Creek Formation. Oepikaluta gen. nov., described from the upper (Undillan) part of the Currant Bush Limestone, shows the trace of four thoracic segments, which is consistent with the hypothesis of the presence of four thoracic limb pairs in the ancestral ostracod.

A Devonian microfauna has been described from the Cravens Peak beds of the Toko Syncline in the Georgina Basin, in a joint paper (with S. Turner, The Hancock Museum, University of Newcastle-upon-Tyne, England; and J.J. Draper, Geological Survey of Queensland) submitted for publication in the BMR Journal. The microfauna consists of thelodont scales - Turinia australiensis Gross, 1971, and T. cf. pagei (Powrie, 1870), abundant eridostracans Cryptophyllus sp., and some ostracods (Healdianella inconstans Polenova, 1974?, and Baschkirina? sp.) The combined evidence of this fauna, and the occurrence of scales of Turinia australiensis in the lower Mulga Downs Group of western New South Wales, suggests a late Early Devonian (Emsian) age for the Cravens Peak beds.

Late Devonian and Early Carboniferous Ostracoda have been examined in well cores and cuttings from the Canning Basin (Amax Ellendale No. 1; Esso Puratte No. 1, Moogana No. 1) and the Bonaparte Gulf Basin (Aquitaine Australia Minerals - shallow drillholes). The identified taxa, and their subsurface distribution, help to test and refine existing local biostratigraphic scales based on Ostracoda.

A preliminary examination was made of cores taken from BMR (Ivanhoe) No. 1 bore containing ostracods in the Lower Devonian Amphitheatre Group, in order to provide stratigraphic assistance to the Darling Basin source rock drilling project.

ROBERT S. NICOLL (assistant A.T. Wilson)

Nicoll continued his studies on Devonian and Carboniferous conodont faunas from Western Australia. A short paper describing the reconstructed multi-element structure of the genus Apatognathus was published; it was based on material from the Devonian of the Canning Basin. Additional field collections were made in the Canning and Bonaparte Gulf Basins. The Canning material was collected for a conodont palaeoenvironmental study to see if conodont distribution can be related to water depth in the steeply dipping fore-reef beds of the Devonian. In the Bonaparte Gulf Basin, Carboniferous samples were collected to fill stratigraphic gaps in previous collections. These mostly related to the upper part of the Burt Range Formation and the Septimus Limestone.

On a visit to the USA a paper on the composition and relationship of elements in the multi-element conodont organism was presented at the North-Central Section meeting of the Geological Society of America in Bloomington, Indiana. Discussions with co-workers at the meeting and later has assisted in the understanding and interpretation of Australian conodont faunas. This is particularly true of the discussion with Dr Gilbert Klapper, of the University of Iowa, on the identification and age range of Kockelella ranuliformis, which appears to have a longer range in Australia than in the rest of the world. Discussions and examination of material were done in Washington, DC, with Dr Anita Harris, of the USGS, on the broad spectrum of conodont color alteration and its interpretation. Unpublished data on color alteration from the western USA was examined; this may show some relevance for a similar study which could be undertaken in parts of Australia to outline areas of economic interest.

M. PLANE (assistant R.W. Brown)

Fossil mammal systematic and chronostratigraphy research continued. The ultimate aim of this work is the biostratigraphic correlation of non-marine sediments and the search for the fossil record of marsupial evolution in Australia. Work continued on the Bullock Creek and Kangaroo Well faunas from the Northern Territory, the Ngapakaldi fauna and Mamelon Hill faunas from South Australia, and the Riversleigh fauna from Queensland.

No fieldwork was done during the year, and laboratory work continued on the material from Lake Palankarrina, Mamelon Hill, Kangaroo Well, Bullock Creek, and Riversleigh. Representation of new taxa is forthcoming from all faunas, but in many cases more material is needed before definitive taxonomic work can be done. Collections have been consolidated and compared at weekend workshops held in Canberra, though some material still needs to be processed.

Joint work is underway with T.H. Rich, National Museum of Victoria, on a new Late Tertiary/early Pleistocene diprotodontid from Papua New Guinea, and the detailed skull morphology of Neohelos from Bullock Creek; with M.A.

Archer, University of New South Wales, on a new diprotodontid from Riversleigh; and with N. Pledge, South Australian Museum, on the Mamelon Hill fauna.

The Oligocene Epoch study continued; borehole data on the Murray Basin were plotted on the data sheets.

Further time was spent on the proposed Palaeontological Store at Fyshwick, construction of which was unfortunately postponed owing to budgetary constraints.

Three months were spent in the USA and Britain. At Berkeley, California, the collection of Australian fossil mammals was examined. Arrangements were made for material to be loaned for study, and discussions were held with Professors Savage and Clemens on future University of California/ Australian joint work. At the American Museum of Natural History, time was spen with the Chairman of the Department of Vertebrate Palaeontology, Dr R.H. Tedford. The fauna from Lake Pinpa, South Australia, was examined in detail, and discussions were held on various aspects of Australian biostratigraphy. In Britain, visits were made to colleagues at the British Museum of Natural History, Bristol University, Hunterian Museum (Edinburgh), and Oxford University, where collections were examined and discussions held.

SAMIR SHAFIK (assistants A.T. Wilson, P.W. Davis)

Work on Australian calcareous nannofossils has concentrated previously on the biostratigraphic use of these fossils, and very little was done on their systematics. However, a study of the systematics of the Upper Cretaceous taxa of Western Australia was initiated in 1980, after a successful attempt at studying the ultra-structures of some nannofossil taxa - using the scanning electron microscope (SEM) - late in 1979. The study will continue into early 1982. A manuscript is being prepared dealing with the systematics and biostratigraphy of the Late Cretaceous nannofossils of the Perth Basin. This manuscript is based on material from the Ginginup corehole No. 1, and supplements an earlier study (published in 1978) which was based on outcrop material from the Gingin area, Perth Basin. SEM illustrations of some ninety nannofossil taxa have been prepared, and descriptions are underway. Based on age-diagnostic species, such as *Marthasterites furcatus*, *Phanulithus obscurus*, *P. ovalis*, and *Broinsonia parca*, the age of the Gingin Chalk in the Ginginup corehole is Santonian to early Campanian (though the possibility of a late Coniacian age for the basal part cannot be ruled out); traditionally this formation was dated as Santonian.

Calcareous nannofossil assemblages from the foraminiferid Hantkenina interval (late Eocene) in the St Vincent and Otway Basins have been investigated, and a manuscript dealing with their biostratigraphic significance is being prepared. The importance of the Hantkenina interval to the local foraminiferal biostratigraphic scheme is that it provides one of the few links to the low-latitude zonation.

Material from Irian Jaya and Victoria was also studied.

J.H. SHERGOLD

Shergold continued to administer the BMR Georgina Basin Project until the end of December 1979. A summary of progress made during the initial five year pilot study, 1974-1979, which is pertinent to the continuation of project management, and a document suggesting future activities in the Georgina Basin for the quinquennium 1980-1985, were prepared.

At the beginning of January 1980, Shergold took up an Alexander von Humboldt Research Fellowship at the University of Wurzburg, West Germany. During the tenure of this fellowship, Late Cambrian and Early Ordovician trilobites from northern Spain and central Turkey were investigated. Three papers concerned with their description and biogeographic relationships are in preparation. Description of Early Ordovician trilobites and Middle Cambrian phosphatised organisms from the Georgina Basin, and Middle and Late Cambrian trilobites from the Transantarctic Mountains collected during recent New Zealand and US Antarctic expeditions, continued. The justification for these activities is the investigation and definition of circum-Gondwana biofacies during the Cambrian, and the relations of the new faunas to those already described in Australia and China. This work, which involves the assessment of previously described collections, and their revision or review, has led to visits to palaeontological institutes in England (British Museum), Spain (University of Zaragoza), France (Universities at Montpellier, Rennes; Palaeontological Institute, Paris), West Germany (Universities of Tubingen, Bonn, Munster; the Senckenberg Museum; and the Bundesanstalt fur Geowissenschaften und Rohstoffe), DDR (Humboldt Museum), and the USSR (Geological Institute, Palaeontological Institute, Moscow), during the course of the year.

International activities - as co-Project Leader of IGCP Project 156, Phosphorites; as co-ordinator of the Cambrian Correlations Working Group of the Commission on Stratigraphy, Subcommission on Cambrian Stratigraphy; and as Vice-Chairman of the COS Cambrian-Ordovician Boundary Working Group - were also conducted on a continuing basis. With respect to IGCP activities, a one day meeting on glauconitic and phosphatic sediments co-sponsored by the Geological Society of London and the IGCP Project 156, was attended in London in February; and the third international field workshop and seminar of Project 156 was attended in June in the Mongolian Peoples Republic. During the latter, phosphorites dated by microflora as Vendian, or even Riphean, were examined in the Khubsugul Basin in northern Mongolia. Circumstantial evidence, however, suggests that these may well be of early Cambrian age, as in southern Kazakhstan and southwestern China. Activities concerning Cambrian correlations on behalf of the COS Cambrian Subcommission were promoted during the 26th Session of the International Geological Congress in Paris in July, when a decision was taken to organise global Cambrian correlation charts as an essential prerequisite for the recognition and definition of subdivisions of Cambrian time. Such correlation charts also form the basis of palaeogeographic reconstruction which are useful in predicting the distribution of sedimentary mineral deposits. Activity within the Cambrian-Ordovician Boundary Working Group has been catalysed by the proposed publication of a book concerned with the problems at this boundary.

The work achieved during the past year provides a contribution to knowledge of Late Cambrian trilobite systematics, biogeography, and biostratigraphy; and through studies on phosphogenesis, to a better understanding of Cambrian biological, chemical, sedimentary, and tectonic systems.

S.K. SKWARKO (assistants R.W. Brown, H.M. Doyle)

Skwarko continued work on the Mesozoic faunas and stratigraphy of Australia, Papua New Guinea, and Indonesia, and participated in the Irian Jaya Geological Mapping Project.

He described a fauna of bivalves, gastropods, and an ammonite from the Croydon-Georgetown area of north Queensland, and prepared manuscript papers for publication in BMR Bulletin 209, entitled Palaeontological Papers. He continued work on the belemnite fauna of the Sula Islands.

He visited Indonesia twice to organise the activities of the Macropalaeontological Research Group Laboratory of the Geological Research and Development Center in Bandung. This included training staff, organising laboratory space and equipment, procuring literature, and the preparing and editing of manuscripts for publication.

He carried out fieldwork in Irian Jaya. Important collections have been made from the Mesozoic and late Palaeozoic. He is working on part of this material, and material has been sent to experts in various parts of the world. Marine Permian is now known to be well represented in the area.

D.L. STRUSZ (assistant R.W. Brown)

Strusz is engaged in a stratigraphic and palaeontological study of Siluro-Devonian rocks in southeastern Australia, particularly those around Canberra. This study is to improve understanding of the geological evolution of the Lachlan Fold Belt, and internationally is making a contribution both in general, to the systematics of the fossil groups concerned, and in particular to the IGCP 'Project Ecostratigraphy'.

On the stratigraphic side, work is progressing towards a revised Canberra 1:250 000 map, by way of 1:100 000 scale mapping being done by Abell (CANBERRA) and Owen and Wyborn (ARALUEN), as reported elsewhere in this publication.

The palaeontological work is concentrating on the shallow-water benthic faunas, which are dominant in the more complex stratigraphic successions on the palaeogeographic "highs" - yet have largely not been described or need revision in the light of the systematic work over the forty years or more since many were first described. A study of the trilobite family Encrinuridae - including redescription of Australian forms (and some new species), and world-wide assessment of this common group - has been published. The description of a Wenlockian brachiopod fauna from Canberra will be completed late in 1981. The trilobites from the same locality have been described in the encrinurid paper, or by Chatterton & Campbell (1980)*, and the ostracods are to be started soon by P.J. Jones. This will be the first adequately documented Wenlockian fauna from Australia.

Further activities during the year have been:

1) Editing of Bulletin 186 (Cambrian trilobites from the Chatsworth Limestone, by J.H. Shergold).
2) Curatorial work on Silurian brachiopod collections from Europe.
3) Curatorial work on the collection of Canberra fossils made by A.A. Opik, and recently presented to BMR.
4) Treasurer and local correspondent for the newsletter Fossil Cnidaria of the International Research Group on Fossil Corals and Coral Reefs.

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*Palaeontographica A, 167, 77-119.

E.M. TRUSWELL (assistants L.J. Kraciuk, P.W. Davis)

Truswell continued palynological research in three main areas: the Australian Permo-Carboniferous, the Australian and Antarctic Tertiary, and the distribution of recycled palymorphs in modern muds around Antarctica.

In the palynology of the Australian Late Carboniferous and Permian, work continued on the Joe Joe Group of the Galilee Basin, Queensland. An overview of progress in the stratigraphic palynology of the Permo-Carboniferous of Gondwanaland was prepared and presented at the 5th International Gondwana Symposium in Wellington, New Zealand, in February. This review has been published in the BMR Journal. Additionally, an account of palynological data relevant to determining the position of the Carboniferous/Permian boundary in Australia was prepared and presented at the 5th International Palynological Conference in Cambridge, England, in June. The main thrust of the argument presented in this paper is that there appear to be no sound grounds for regarding the Australian palynological Stage 2 as Permian; the horizon equivalent to the basal Asselian of the Russian type sequence lies probably within Australian Stage 3.

In Tertiary palynological and palaeoclimatological work, available data from within the Australian arid zone was summarised in a paper prepared jointly with W.K. Harris, 'The palaeobotanical record in arid Australia'. This was a review invited by the organisers of a symposium on the evolution of the flora and fauna of arid Australia, which was held in Adelaide in May. New information presented in that review included data from Glen Florrie in northwestern Australia and from Goat Paddock in the Kimberleys, which sites extend the formerly known distribution of Early Tertiary rainforest. Data from the Hale River Basin in central Australia suggest the development there of grasslands in the Eocene, which is much earlier than in coastal regions; indeed, on a global basis these may be some of the oldest-known grasslands. The proceedings of the Adelaide conference are to be published.

Work on Antarctic offshore palynology has continued; recycled material from the sea floor near the Shackleton Ice Shelf strongly suggests that Paleocene-Eocene sediments are being eroded nearby. In the Ross Sea, counts of the absolute frequencies of recycled pollen per gram of sediment suggest that the source of Early Tertiary/Late Cretaceous material lies in west Antarctica; somewhere south of Roosevelt Island. The rarity of recycled pollen in the MSSTS 1 borehole, drilled in McMurdo Sound by a New Zealand team, confirms this. The near-absence of pollen from the middle Miocene part of the sequence drilled at this site also sheds doubt on the persistence of coastal vegetation in

Antarctica up to that point in time; mid-Miocene vegetation had been suggested earlier on the basis of palynological assemblages from beneath the Ross Ice Shelf. Results of the bottom-sediment studies were presented at the 4th Australian Geological Convention in Hobart in January, and at the 26th International Geological Congress in Paris in July.

Other activities during 1980 included teaching a course in palynology to third year geology students at the Australian National University from March to June, and involvement with the organising committee for Section 11 (Historical Botany) for the 13th International Botanical Congress, to be held in Sydney in August 1981. At this congress, Dr Truswell is also convenor of a symposium on the development of regional vegetation types in the pre-Quaternary. Six overseas speakers and two Australians have accepted invitations to participate in this symposium, which covers the principles underlying recognition of ancient plant provinces, and the development of these through the Devonian-Tertiary interval.

Dr Truswell represented Australia at the SCAR Working Group on Geology meetings in Paris in July (standing in for R.J. Tingey). An invitation was presented there on behalf of Australia for the next symposium on Antarctic Geology and Geophysics; this is scheduled for Adelaide in 1982, to correspond with the centenary of Sir Douglas Mawson's birth. Dr Truswell has also served on the organising committee for the symposium on the Cainozoic evolution of southeastern Australia, held in Canberra in November 1980.

G.C. YOUNG (assistants R.W. Brown, H.M. Doyle)

The study of Palaeozoic vertebrate faunas from various regions in Australia and south Victoria Land, Antarctica, continued. Research objectives are to provide a systematic basis for correlation of non-marine and marine Palaeozoic sedimentary rocks, and for biogeographic analysis relevant to the solution of geological problems, using contained vertebrate faunas. To this end, two further manuscripts have been submitted to Alcheringa for publication, one dealing with biogeographic analysis of Devonian vertebrate faunas world-wide, and the other describing new placoderm fishes from NSW. Some time was spent updating a manuscript submitted in the previous year for publication in the BMR Bulletin 209, and several manuscripts were refereed for outside journals. Papers were presented at the 4th Australian Geological Convention (Hobart, January) and the 5th Gondwana Symposium (Wellington, NZ, February). No major fieldwork was undertaken, but development and curation of previously collected material progressed in the laboratory, with the addition of 166 specimens to the vertebrate fossil register. Preparation of the 1974 Georgina Basin collection was completed, and work continued on the 1977 collection, continued in which several new forms not described from other localities (but possibly represented in the Mulga Downs Group of western NSW) were identified in material from the Cravens Peak beds. Acetic acid preparation continued on material from the Gogo Formation (Canning Basin), the Taemas/Wee Jasper region of NSW, and the Broken River Formation (Qld), and vertebrate microfossil residues from this work were studied and curated. The Queensland material (collected by Drs J. Jell and M. Wade in 1979) is of interest in representing two vertebrate assemblages of Eifelian/ Givetian age not previously recognised in Devonian successions from other basins. Preparation and curation of the 1970/71 Antarctic collection continued, and descriptions of antiarchs from this fauna are now almost finished; results from this work support previous indications of close affinity between south China and east Gondwana during part or all of Devonian time.

PALAEONTOLOGICAL LABORATORIES

by

A.T. Wilson

During the year 1300 samples were washed for microfossil examination, 600 thin sections prepared, and 27 samples polished; 500 slides of nannofossils were prepared from 125 samples. In the Acid Digestion Laboratory, Fyshwick, 1700 samples totalling 6,800 kg were processed for extraction of conodonts, 900 samples were picked for ostracods and Conchostracans. The Palynological Laboratory prepared 800 slides from the 230 samples processed.

Macropalaeontological work included the mechanical and acid preparation of 36 mammal and 175 fossil fish samples, the making of 1400 rubber replicas or plaster casts of fossils, and the picking of 2 1/2 tonnes of material for mammal remains.

Frank Hadzel, officer in charge of the laboratory, retired in August after 27 years service in BMR.

ESCAP STRATIGRAPHIC ATLAS (IGCP PROJECT 32)

by

H.F. Doutch

STAFF: H.F. Doutch (Project Leader), V.L. Passmore, C.M. Brown

The ESCAP (UN Economic Commission for Asia and the Pacific) project aims to produce an atlas of stratigraphic columns and brief explanatory notes to be used for correlation in and between the sedimentary basins of the region. Objectives of the project are to determine the nature, structure, age, thickness and facies of sedimentary sequences within the region, in order to further knowledge of the distribution of economic minerals, particularly hydrocarbons.

The atlas will include columns and notes on many Australian basins; the notes outline the stratigraphic and structural evolution of the basins, and describe the geological setting of known and potential resources.

None of the material so far sent to ESCAP has been published, but much of it is in press. This includes contributions on the Carpentaria, Karumba, Laura, Sydney, Arafura, Money Shoal, Bonaparte, and Carnarvon Basins. In the last twelve months V.L. Passmore completed a contribution on the Browse Basin, and C.M. Brown began one on the Murray Basin. All contributions except for the Murray Basin are also BMR Records.

The slowing down of work for the project reflects the lack of a co-ordinator in Bangkok since the return of Dr D.J. Belford to BMR after finishing his tour in that position at the end of 1979 (see his report in the previous section).

BMR EARTH SCIENCE ATLAS OF AUSTRALIA

by

G.E. Wilford

(see also p. 180)

STAFF: H.F. Doutch, A.T. Wells, G.E. Wilford

Compilations were prepared for atlas sheets showing Sedimentary Sequences, Petroleum and Oil shale, and Coal. Commentaries for each sheet are in preparation.

The Sedimentary Sequences sheet depicts sedimentary basins according to the age of initiation of widespread deposition within them. The thicker sedimentary sequences in basement provinces are also shown. Letter symbols indicate the time ranges of sedimentation and tectonic events affecting them, and isopachs show the thicknesses of some of the better-known sequences. The map covers both continental and offshore areas.

The Coal sheet shows coal measure sequences according to age and depth of burial, together with structural information and an indication of areas affected by igneous intrusions. The economic importance of the established coal-fields is illustrated by histograms showing coal production and reserves.

The Petroleum and Oil Shale sheet shows the locations of oil and gas fields and oil shale occurrences. The stratigraphic distribution of oil, gas and oil shale is depicted, together with petroleum reserves (see Fig. S7).

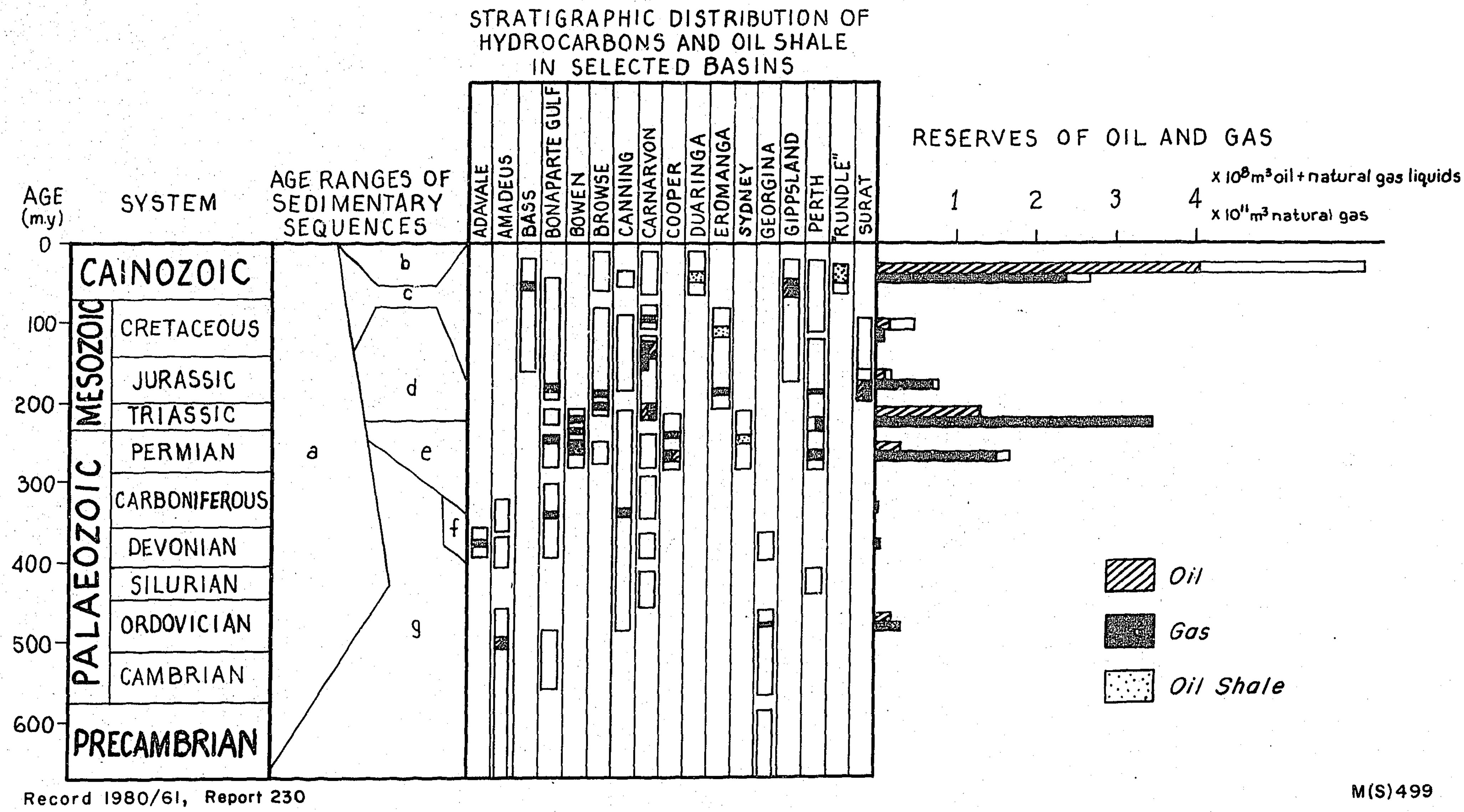


Fig. S7 Stratigraphic distribution of oil, gas and oil shale in selected basins. Blank areas on bar charts indicate reserves produced to the end of 1979

COAL STUDIES

PERMIAN COALS OF EASTERN AUSTRALIA

by

H.J. Harrington

BMR STAFF: H.J. Harrington, A.T. Brakel, G. Waters, A.R. Jensen.
(CSIRO STAFF: M. Middleton, J. Hunt, M. Ziekenheiner, G.H. Taylor, M. Shibaoka).

In January 1979 the Minister for National Development approved payment of a grant under the National Energy Research Development and Demonstration (NERDD) Program to support a project to be undertaken jointly by CSIRO and BMR, to collate and interpret the very large body of available information on the Permian coals of eastern Australia, with special emphasis on the Sydney and Bowen Basins.

The project aims to provide an understanding of the relation between: a) the nature and quality of coal, and the factors affecting its economic recovery, considered on a regional scale; and b) the environment of deposition of coal measure rocks and their subsequent geological history.

The study will show the geological basis of the properties of coal, and the variability of coal on a scale larger than can be considered in connection with a single colliery or even a single coalfield, and will enable the occurrence of coal to be predicted in areas where little or no knowledge now exists.

The central activity in the project will be the construction of a series of maps, as detailed as possible, covering the palaeogeography and sedimentology of the Permian Period in eastern Australia. To these maps will be added information on coal type and properties determined for the time of deposition. Each palaeogeographic reconstruction will be regarded as a starting point in considering the subsequent geological history - including burial, igneous intrusion, tectonic disturbance, and stripping of overburden by erosion - from both field evidence and the evidence of coal properties.

All staff having been appointed and taken up duty, the project started on 1 March 1980. It was arranged that the work on coal properties such as rank, coal type, and sulphur content would be done mainly by the CSIRO team. Structural and stratigraphic studies would be undertaken mainly by the BMR team. Both teams started work in the Sydney Basin, where the first round of work was completed in August. The first round of work in the Bowen Basin will be completed in December 1980. Control points have been selected in both basins, and are usually major boreholes which were cored and studied in detail when they were first put down. Large amounts of data have been stored in the CSIRO and BMR computer systems, and a system is being developed for the machine-drafting of maps and diagrams.

COAL BASIN REVIEW

STAFF: A.T. Wells

A compilation of the basic data on all coal deposits in Australia is proceeding. The compilation aims to tabulate not only the pertinent geological data on a coal province but also indicate where relevant knowledge on areas, or aspects of the deposits, is lacking.

An Australian coal resources map was compiled for the Geographic Branch of the Division of National Mapping. The map at 1:12.5 million scale shows producing, potential, and subeconomic occurrences of black and brown coals in Australia together with an indication of main projects, prospects, and coal-loading facilities.

OIL SHALE STUDIES

OIL SHALE METHODOLOGY PROJECT: TOOLEBUC FORMATION INVESTIGATIONS

by

H.F. Doutch

STAFF: H.F. Doutch, S. Ozimic

In January 1979 the Minister for National Development approved payment of a grant under the National Energy Research Development and Demonstration (NERDD) Program to support a project to be undertaken jointly by CSIRO and BMR, to develop methods to assist government and industry to assess the potential of a widespread sedimentary sequence as a possible future source of oil shale. The project is initially based on a study of the Toolebuc Formation of the Eromanga Basin of South Australia, New South Wales, and Queensland. Samples from current and past drilling programs will be examined for rock type and organic content, both microscopically and chemically, and these results will be correlated with geophysical logs of the drillholes. Stemming from this work the geological controls for the accumulation of the oil shale will be deduced, and the significance of this information in assessing oil shale resource potential evaluated.

Work in BMR on the project began at the end of February 1980. Dr Ozimic has since been collecting information on the Toolebuc Formation from companies and State Geological Surveys.

BMR has also drilled and logged BMR Urisino 1 130 km east of Tibooburra, NSW, jointly with the Geological Survey of New South Wales (GSNSW). A density logging sonde was hired to supplement BMR's collection of logging tools. Thirty three cores were recovered, and cuttings taken from all strata not cored. Total depth was 149 m. No oil shale was found, although preliminary palynological studies by both BMR and GSNSW indicate that limestones and siltstones of the same age as the Toolebuc Formation were cored. A gamma-ray anomaly was recorded from just below these beds. Lithostratigraphy generally was similar to sequences of the same age near and southeast of Oodnadatta, South Australia, and oil shale thus seems likely to be absent from the Toolebuc Formation equivalent at least between Oodnadatta and BMR Urisino 1. CSIRO was still analysing Urisino 1 samples at the time of writing.

Later, fourteen shallow holes were drilled by contract and logged by BMR between Longreach and Charleville in Queensland (Fig. S8). Once again a density logging tool was hired. The cumulative depth drilled was 888.3 m, of which 426.2 m was cored; cuttings were collected from strata not cored. Unsuspected structure resulted in two holes not reaching the Toolebuc Formation. In all but two of the other holes, oil shale was obvious, although less so in the south than the north. Traces of hydrocarbons were recovered in the drilling mud from eight of the holes. CSIRO will be analysing samples during 1981.

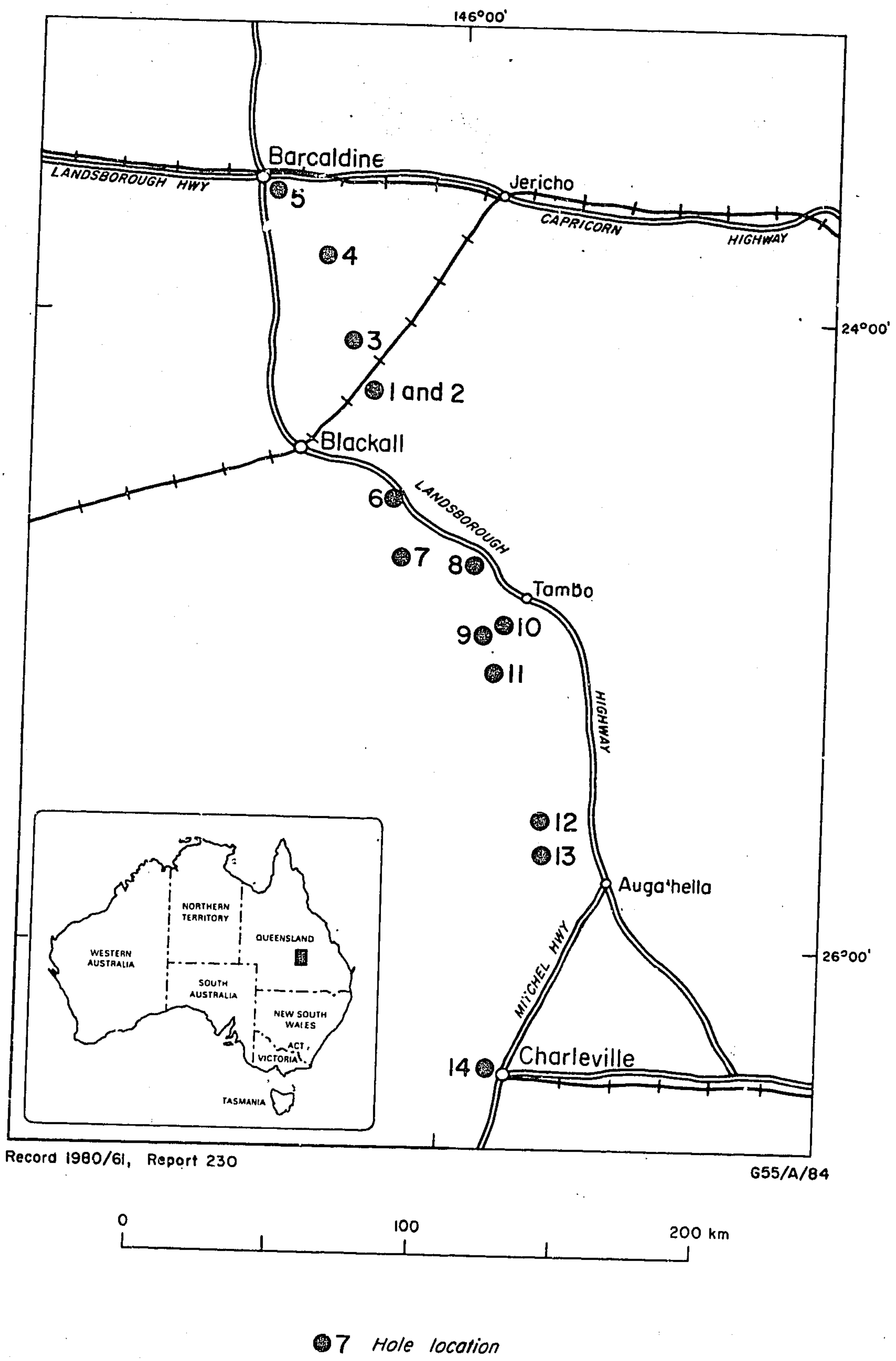


Fig. S8 Oil shale stratigraphic holes drilled in Queensland, 1980

METALLIFEROUS SECTION

Head: K.R. Walker

GEOLOGICAL INVESTIGATIONS IN THE NORTHERN TERRITORY, WESTERN AUSTRALIA, AND ANTARCTICA

Supervising Geologist: R.G. Dodson

ARUNTA PROJECT

by

R.D. Shaw, R.G. Warren A.J. Stewart

STAFF: Full Time - R.D. Shaw
Part Time - L.A. Offe, A.J. Stewart, A.Y. Glikson, B.R. Senior, and R.G. Warren (BMR); M.J. Freeman and C.L. Horsfall (Northern Territory Geological Survey)

The objectives of the Arunta Project are to obtain, study, and make available basic geological and economic mineral data on the Arunta basement in central Australia, so as to provide a basis for understanding the geological evolution of the region, and as an aid to exploration of the region's mineral resources.

The main results of the year's work are:
(see DATA PRESENTATION below for more details)

1. Mapping of the southern half of Huckitta 1:250 000 Sheet area at 1:100 000 scale.
2. Continued progress in map production in areas already investigated: two 1:250 000 scale 2nd Edition maps and one set of Explanatory Notes are with the editors; two composite 1:100 000 scale 1st Edition special maps and Commentaries are with the editors and a third is ready to go to the printer; one Preliminary 1:100 000 scale map was printed, and another seven are in various stages of drafting.
3. Publication of a microfiche Record giving the results of 1:100 000 scale mapping in the Alice Springs 1:250 000 Sheet area; a second microfiche Record on the 1:100 000 and 1:250 000 scale mapping in the northern Arunta Block is with the editors.
4. Completion of a Record summarising the data on known mineral deposits in the Alice Springs 1:250 000 Sheet area; this is with the editors.
5. Publication of a report listing definitions of named stratigraphic units in the Arunta Block.

6. Contributions to outside journals dealing with the age of the Stuart Dyke Swarm near Alice Springs, geosutures in Australia, magnetic interpretation in basement terrains, and a contribution to a book on the Proterozoic rocks of northern Australia.

DATA PRESENTATION

ALICE SPRINGS 1:250 000 SHEET AREA

The Preliminary 1:250 000 map of the 2nd Edition of Alice Springs was issued; the 2nd Edition map is with the editors and the Explanatory Notes are in the final stages of preparation. Composite 1:100 000-scale maps and Commentaries of the Strangways Range and Alice Springs Regions are with the editors. Drafting of the RIDDOCH Preliminary map is almost complete. A large and detailed microfiche Record on all the above 1:100 000 areas mapped has been issued, and a separate Record giving detailed information by commodity on known mineral deposits should be issued shortly.

HERMANNSBURG 1:250 000 SHEET AREA

The MACDONNELL RANGES Preliminary map is almost complete. Compilation sheets have been prepared of ANBURLA and NARWEITOOMA, and compilation of GLEN HELEN is in progress.

NAPPERBY 1:250 000 SHEET AREA

The special 1st Edition map of the Reynolds Range Region is being contract drafted, and the colour scheme has been chosen. The Commentary on the Reynolds Range Region was completed, edited, and is ready to go to the printer. The draft manuscript of the detailed microfiche Record on 1:250 000 and 1:100 000 scale mapping in the northern Arunta Block was completed, and was being edited at the end of the year. A 2nd Preliminary Edition of the Napperby 1:250 000 She t was published, Explanatory Notes written, and both Map and Notes were with the map editors at the end of the year. The DENISON Preliminary map was issued in March.

ALCOOTA 1:250 000 SHEET AREA

The updated Record 1975/100 has been printed on microfiche.

ILLOGWA CREEK 1:250 000 SHEET AREA

A draft of the Record of 1979 fieldwork is substantially complete and preparation of compilation sheets well advanced. A 2nd Edition 1:250 000 scale map of Illogwa Creek and Preliminary1:100 000 maps of QUARTZ and LIMBLA will be produced.

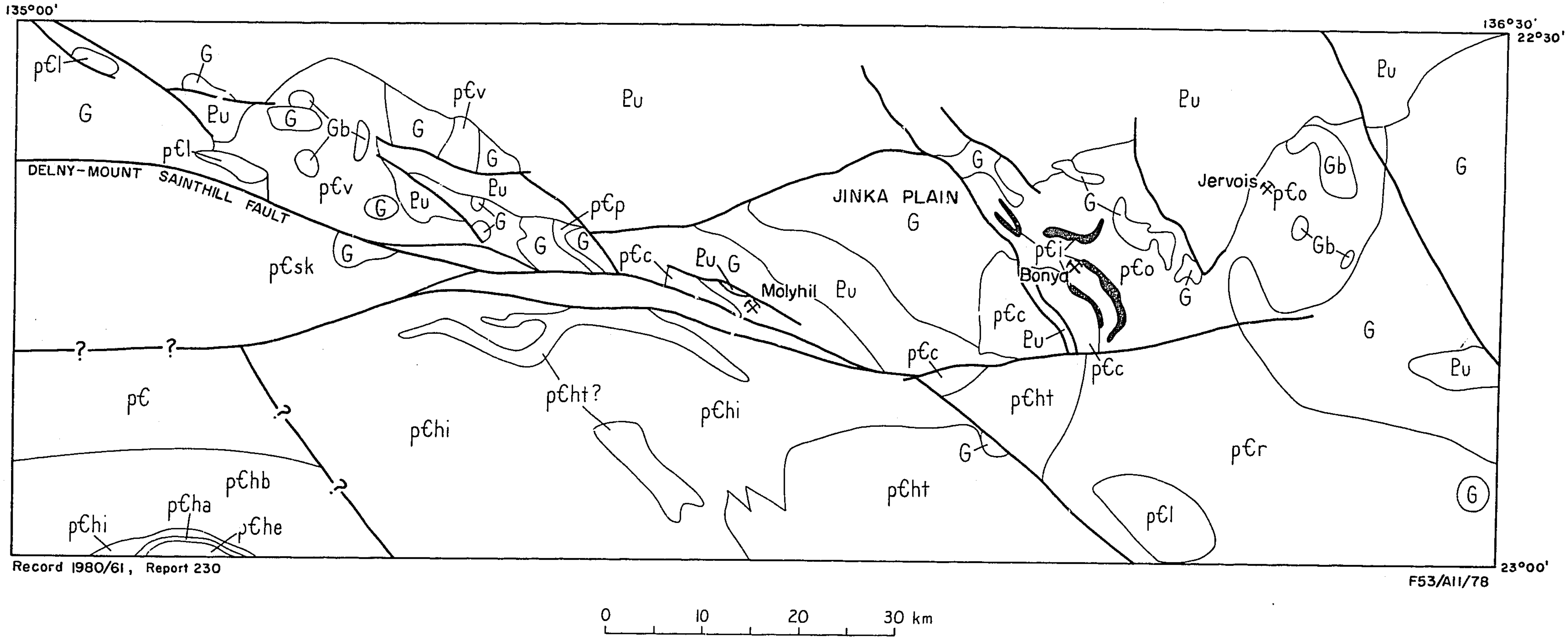
FIELD ACTIVITIES

HUCKITTA 1:250 000 SHEET AREA by R.D. Shaw & R.G. Warren

Introduction

The southern half of the sheet area was mapped at 1:100 000 scale in co-operation with M.J. Freeman and C.L. Horsfall of the Northern Territory Geological Survey. A simplified interpretation of the geology is shown in Figure M1. Field research this year has resulted in:

1. confirmation that a major change occurs across the Delny-Mount Sainthill Fault - north of the Fault the rock units are very like those in the northern Alcoota 1:250 000 Sheet area whereas south of the fault they are like rock units in the southern Alcoota, Alice Springs, and Illogwa Creek 1:250 000 Sheet areas;
2. correlation of the Bonya and Jervois sequences which are to be referred to collectively as Bonya schist (Fig. M2);
3. identification of facing that shows both sequences young eastwards;
4. confirmation that basic rocks in the Bonya area - previously mapped as intrusions - are amphibolite, probably derived from basalt (Kings Legend Amphibolite - Fig. M2);
5. recognition that the large Jinka and Jervois Batholiths in the northeast of the mapped areas are biotite granite not muscovite granite as shown on the Huckitta 1st Edition map (1964); confirmation that the area shown as Dneiper Granite is occupied by several discrete granites;



* *Informal name*

Ꝑu	*Late Proterozoic and Palaeozoic sedimentary rocks; (Georgina Basin sequence)*
Gb	*Gabbro, dolerite; some partly metamorphosed*
G	UNDIVIDED GRANITE–*K-feldspar-rich granite, leucogranite, porphyritic granite*
pЄl	*Quartzite, schist*
pЄ	*Inferred metamorphic rocks*
pЄhb	BRADY GNEISS–*Garnet-muscovite-biotite schist, muscovite-biotite gneiss*
pЄht	ATULA METAMORPHICS*–*Calc-silicate rock, migmatitic biotite gneiss, metasediment, muscovite-biotite gneiss*
pЄhi	IRINDINA GNEISS–*Garnet-biotite gneiss, sillimanite gneiss, (schistose biotite gneiss)*
pЄha	BRUNA GNEISS–*Porphyroblastic feldspar gneiss*
pЄhe	ENTIA GNEISS–*Quartzofeldspathic gneiss, layered amphibolite*
pЄr	*Migmatitic quartzofeldspathic and biotite gneiss, muscovite-biotite schistose gneiss, some calc-silicate and quartz-magnetite rocks*
pЄo	BONYA SCHIST*–*Muscovite and muscovite-biotite schist, andalusite schist, calc-silicate rock, amphibolite, banded quartz-magnetite rock*
pЄi	KINGS LEGEND AMPHIBOLITE–*Amphibolite*
pЄc	CHARLOTTE GNEISS COMPLEX*–*Granitoid, quartzofeldspathic gneiss, hornblende gneiss, layered amphibolite, metasediment*
pЄv	CACKLEBERRY METAMORPHICS*–*Biotite gneiss, calc-silicate rock, layered amphibolite, quartzofeldspathic gneiss, cordierite gneiss*
pЄp	DEEP BORE METAMORPHICS*–*Cordierite quartzite, garnet quartzite, calc-silicate rocks, rare mafic granulite and sillimanite gneiss*
pЄsk	KANANDRA GRANULITE–*Felsic gneiss, mafic granulite*

Fig. M1 Generalised solid geology of southern half Huckitta 1:250 000 Sheet area

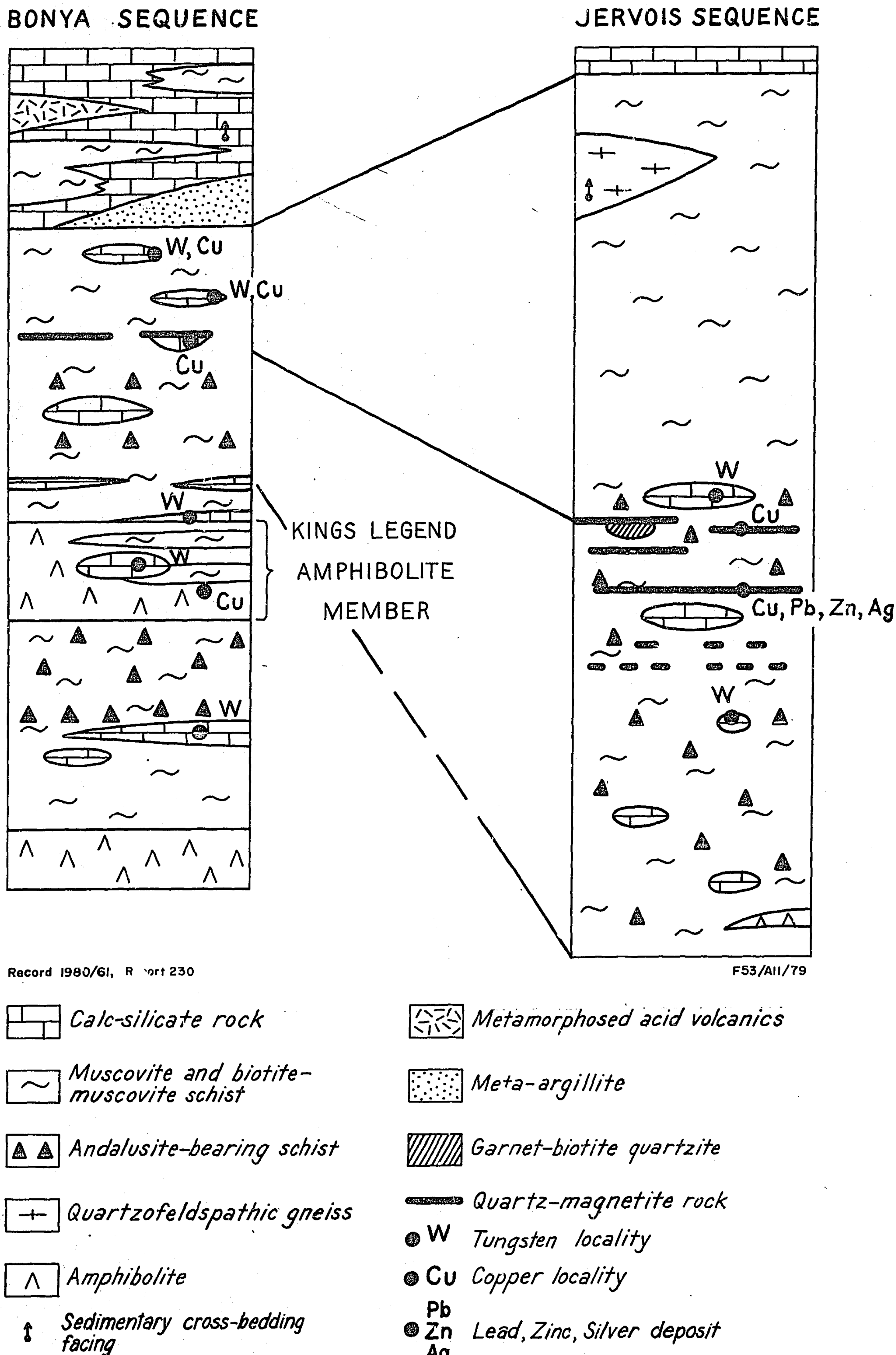


Fig. M2 Bonya Schist – correlation of the Bonya and Jervois sequences.

6. recognition that the Atula metamorphics may be a facies equivalent of the Irindina Gneiss;
7. confirmation that most of the tungsten mineralisation is stratabound in epidote-rich calc-silicate rocks.

Stratigraphy, lithology

Stratigraphic subdivision was based on the concept of three broad lithological groupings, termed Divisions, which are applied throughout the Arunta Block and have been outlined in Record 1979/47 and elsewhere.

Division I rocks, thought to be the oldest, occupy a fault block in the west of the area and are an extension of the Kanandra Granulite previously mapped farther west. They consist of felsic gneisses, subordinate mafic granulite, and minor calcareous metasediments, and are thought to have originally been a bimodal volcanic sequence containing minor calcareous rocks. The felsic gneisses are mainly garnet-bearing and typically migmatitic. Extensive retrogression to amphibolite facies assemblages is common close to faults.

The Deep Bore metamorphics (informal) is a poorly exposed unit of cordierite-bearing quartzite, garnet-bearing quartzite, garnet-sillimanite gneiss, calc-silicate rock, rare marble and mafic granulite. It is retrogressed particularly at its contact with granite (Marshall Granite) and is intruded by a small biotite-bearing gabbro. Although it includes a high proportion of quartz-rich metasediments it does not have the high-grade equivalent of the potassic muscovite-rich assemblages typical of the nearest Division III rocks (Utopis Quartzite - Alcoota 1:250 000 Sheet area) and is, therefore, tentatively assigned to Division II.

A series of fine-grained, plagioclase-rich felsic gneiss, para-amphibolite, biotite gneiss, minor cordierite-bearing felsic gneiss, and rare cordierite-anthophyllite granofels, mapped as Cackleberry metamorphics (informal), crops out in the northwest of the mapped area. It has been metamorphosed to the upper amphibolite facies and is intruded by gabbro, dolerite, several granites, and pegmatites. The unit is thought to have originally been a sequence of marine sediments containing calcareous, dolomitic and potassium-rich components. Lithological similarities to the Delmore Metamorphics (Alcoota 1:250 000 Sheet area) favour assignment of this unit to Division II.

The Town Hill metamorphics (informal) crops out just outside and to the northwest of the area illustrated in figure M1. They consist of well-layered felsic gneiss, metaquartzite - locally containing cordierite and sillimanite - and minor calc-silicate gneiss. These rocks are considered to be sediments metamorphosed to upper amphibolite or granulite grade. Anorthositic norite, granite (Mount Swan Granite), and dolerite intrude the metamorphics. The lithological affinity of the unit is uncertain and it is tentatively assigned to Division II.

The Charlotte gneiss complex (informal), consisting mainly of granitoid and layered quartzofeldspathic gneiss, underlies the Bonya schist (informal) with a transitional contact in the northeast of the mapped area. It probably extends west for about 30-40km. Kornerupine-bearing quartzofeldspathic gneiss occurs in one mass, which is tentatively assigned to this unit. The quartzofeldspathic gneiss sequence is lithologically similar to the Albarta metamorphics in the southern part of the Illogwa Creek 1:250 000 Sheet area, and the unit is assigned to Division II on this basis.

The sequence in the Jervois Mine area is correlated with the upper part of the sequence in the Bonya Mine area and both are now referred to as the Bonya schist (Fig. M2). Preliminary facing determinations based on cross-bedding suggest that both sequences young eastwards. In both sequences, amphibolite-bearing units are overlain by a sequence of quartzofeldspathic muscovite-bearing schist which includes small amounts of andalusite schist, calc-silicate rock, and finely layered quartz-magnetite rock. These schists are overlain, in turn, by more calcareous sequences.

A poorly outcropping, deeply weathered, and enigmatic mass of migmatitic quartzofeldspathic and biotite gneiss, muscovite-biotite schistose gneiss, small amounts of calc-silicate rock and rare layered quartz-magnetite rock, referred to as p€r, occur south of the Bonya schist. Along their southern edge these rocks are in contact with quartzites and schist shown as p€l in Figure M1 which are very like Division III rocks (Utopia Quartzite, Ledan Schist) in the Alcoota 1:250 000 Sheet area.

Highly altered gabbroic intrusive rocks intrude the northern sequences and are thought to have preceded granite intrusion. Dolerite dykes intrude the Cackleberry metamorphics.

The large Jinka and Jervois granite batholiths in the central-north and east, and numerous small granite bodies intrude the northern sequences whereas in the south granites are rare. The granites are typically rich in K-feldspar and biotite granite - they are not muscovite granite as shown on the Huckitta

1st Edition map (1964). The smaller Marshall Granite, which largely encloses the Deep Bore metamorphics (Fig. M1), is predominantly hornblende-bearing granite, but includes a minor phase of coarse-grained feldspar-quartz granite with a graphic texture. Layered and brecciated, multiphase quartz veins, referred to as Oorabra Reefs cut both the Jinka and Jervois batholiths. At least one phase of veining is considerably younger because they also cut basal units of the unconformably overlying Upper Proterozoic sedimentary sequence of the Georgina Basin.

South of the fault block made up of Kanandra Granulite the rocks belong principally to the Harts Range Group. The most widespread unit is the Irindina Gneiss, typified by a greater abundance of biotite and sillimanite and less garnet than in gneiss of the type area in western Illogwa Creek 1:250 000 Sheet area. The Irindina Gneiss can be traced southwards where it grades into a calcareous facies, mapped as the Atula metamorphics in the Illogwa Creek 1:250 000 Sheet area. Similar calcareous units intercalated with Irindina Gneiss farther north may also be Atula metamorphics.

Economic geology

Tungsten mineralisation is localised in calc-silicate rocks in two different settings:

(1) At the Molyhill Mine, scheelite, molybdenite, pyrite, and a trace of chalcopyrite occur in a magnetite/calc-silicate rock which forms a lenticular roof pendant in leucogranite lithologically like the Marshall Granite.

(2) In the Bonya area, scheelite is localised in epidote-rich layered calc-silicate horizons in the Bonya schist, above, below, and within the Kings Legend Amphibolite Member. Scheelite also occurs in similar calc-silicate rock 4000 m above the Member and also in the calc-silicate lenses near the Jervois Mine. Traces of copper carbonate commonly occur on exposures of scheelite-bearing calc-silicate rock.

Copper-lead-silver lodes at Jervois are closely associated with lenses of finely layered quartz-magnetite rock in a sequence of muscovite-rich schist containing disseminated andalusite. Chalcopyrite and galena are the primary minerals in a zone which appears rich in chlorite, quartz, and garnet. Copper mineralisation associated with the quartz-magnetite lenses is similar to the environment at Squirrel Hill near Mount Isa.

Traces of copper carbonate in quartz veins are localised in the Kings Legend Amphibolite Member. Several copper deposits, including the Bonya Mine form cross-cutting orebodies in a variety of country rocks and are considered to be hypogene.

Fluorite and barite occur within several of the Oorobra Reefs in the southern part of the Jinka Granite. Several veins up to 1 km long and up to several metres wide contain from 5 to 70 percent fluorite.

Small magnetite bodies in gabbro 8-10 km northeast of Jervois Mine contain traces of copper and vanadium.

ILLOGWA CREEK 1:250 000 SHEET AREA by L.A. Offe

Further attempts were made made to resolve the relation between the Atula metamorphics, characterised by calcareous rocks, and the Brady Gneiss, typified by slightly garnetiferous schistose gneiss. The sequence containing calcareous rocks overlying the garnetiferous schist unit in the northwest corner of the Sheet area is now considered to be an upper subunit of the Brady Gneiss. However, a similar sequence on the plains to the east characterised by migmatitic biotite gneiss and containing little muscovite-bearing schistose gneiss, but including calcareous rocks, is assigned to the Atula metamorphics. these rocks outcropping on the plain are regarded as facies equivalents of the Irindina Gneiss, which conformably underlies the Brady Gneiss.

The spectacular southwards thickening of the Irindina Gneiss with the incoming of the Stanovos gneiss member was confirmed, but the suspected disconformity at the base of the Brady Gneiss was not substantiated.

MISCELLANEOUS ACTIVITIES

R.D. Shaw gave a BMR Tuesday morning lecture on 'Revisions to the geology of the Southeast Arunta Block', which was repeated in Alice Springs in October. He also contributed to a paper with S. Mathur (Geophysical Branch) on 'The geophysics and geology of geosutures in Australia - a review' to be published in Precambrian Research.

A.J. Stewart spent two weeks in June and July assisting the Map Compilation Group with preparation of the Metamorphic Map of Australia for display at the 26th International Geological Congress in Paris in August, and with preparation of the Geological Map of Australia at 1:5 000 000 scale for the Atlas of Australian Resources.

R.G. Warren, while on long service leave, presented a paper on volcanogenic ore deposits in the Arunta Block at the Fourth Geological Convention in Hobart.

DARWIN OFFICE
by
C.E. Prichard

STAFF: C.E. Prichard, N.A. Ashmore, A.J. Neilson

The base, store, and workshop at Tannadice Street is still unstaffed. Security has been upgraded and individual lockable bays for party use were provided during the year. Fire-fighting equipment was also updated. Eighteen motor vehicles and twelve trailers were stored there after the 1979 field season by field parties working in the area. Most parties also left stores. In 1980 four of these parties collected their vehicles and stores at the beginning of the season. In addition the Goat Paddock Party used Tannadice Street as the base for their survey.

The Woods Street office remains the point of contact with the public. Sales of publications and maps increased and averaged about 130 per month. Exploration companies purchase more maps per sale than the majority of enquirers, who are prospectors, school staff or students, and members of the general public. Many sales involve discussion and advice, especially regarding school excursions and projects. Two classes from Darwin high schools visited the office during the year.

Two local applicants for Mineral Economist positions in BMR were given preliminary interviews, and an applicant for a Technical Assistant position in National Mapping was interviewed.

Operation of Manton Seismic Station continued; weekend changing of records by contract was introduced in November 1979. Landline failures were the major cause of lost records. Since July 1980, preliminary interpretation of ASP Seismic Station has also been carried out here. First arrivals for both stations are telexed to the Observatory Section several times a week, and original records are forwarded regularly. Action has been initiated to have MTN recording units moved to a more permanent location at the Tannadice Street base.

PINE CREEK GEOSYNCLINE PROJECT

by

R.S. Needham, I.H. Crick, P.G. Stuart-Smith, and D.A.Wallace

STAFF: R.S. Needham (project leader), I.H. Crick, P.G. Stuart-Smith, D.A. Wallace, L. Bagas, E. Dwyer (N.T. Geological Survey), I.C. O'Donnell, T.W. Brown (draftsmen)

INTRODUCTION

The objectives of this project are:

1. To research the Precambrian geology of the Pine Creek Geosyncline, revise stratigraphy and structure, and construct the sedimentary, igneous, and metamorphic history.
2. To indicate the controls and distribution of uranium and other mineralisation in the geosyncline.
3. To publish the results as reports and papers, prepare 1:100 000-scale geological maps, and revise the 1:250 000-scale geological maps of the region.

Work done for this project by the Antarctica and Northern Territory Subsection of the Metalliferous Section is reported here. Other aspects of the multidisciplinary program are reported elsewhere in this Report (geochemistry G. Ewers, P. Scott, B. Cruikshank, J. Ferguson; geochronology R. Page), or in the Geophysical Branch annual summary of activities (geophysics A. Mutton, A. Warnes; palaeomagnetics M. Idnurm, J. Giddings).

The project encompasses the following major tasks:

1) Study of the geology and mineralisation of the Alligator Rivers uranium field.
2) Study of the geology and mineralisation of the Rum Jungle uranium field.
3) Study of the geology and mineralisation of the South Alligator Valley uranium field.
4) Study of the Lower Proterozoic stratigraphy of the Pine Creek Geosyncline.
5) Study of the geology and mineralisation of the Cullen mineral field.
6) Synthesis of the geology and mineralisation of the Pine Creek Geosyncline.

Other tasks include study of evaporites and their role in uranium ore genesis, interpretation of Landsat imagery (reported elsewhere in this Report), and gamma-ray spectrometry of granites.

To date eighteen 1:100 000 Sheet areas have been covered by semi-detailed fieldwork; thirteen Preliminary standard series 1:100 000 maps and one Preliminary special 1:100 000 map have been issued, and five more standard series Preliminary maps are at an advanced stage. One 1st Edition coloured 1:100 000 geological map has been issued, and two more standard series and one special are in progress. One Preliminary to 2nd Edition 1:250 000 map has been issued. Field compilation sheets, mainly at 1:25 000 or 1:50 000 scale, are available for all areas investigated to date. During 1980 emphasis has been on petrological studies of rocks from McKINLAY RIVER; on fieldwork in PINE CREEK, RANFORD HILL, and NOONAMAH; study of granites and mineralisation in the Cullen mineral field; and preparation of maps, map Commentaries, and Explanatory Notes for the Alligator Rivers uranium field.

With current manpower the geological investigations and reporting will be complete in about 5 years.

REPORTING AND PROGRESS OF MAP PRODUCTION

Progress of map production is shown in the frontispiece and in Fig. M3. The MUNDOGIE Preliminary map was issued during the year. Checking of the final draft of the MARY RIVER/POINT STUART Preliminary map is in progress, and the McKINLAY RIVER map awaits checking. The EAST ALLIGATOR 1st Edition map has been issued, and CAHILL and NABARLEK 1st Edition maps are in preparation; Commentaries have been prepared for these and are being edited. The 1st Edition Alligator River 1:250 000 map has been issued as a Preliminary, and the coloured edition and Explanatory Notes are being edited. A Bulletin describing the geology of the Alligator Rivers uranium field is being prepared. A data Record containing compilation sheets and thin-section descriptions from MARY RIVER/ POINT STUART area was issued, and a Record describing the geology of MUNDOGIE is in press. A Record describing the results of drilling in the Munmarlary area in 1978 was also issued.

The papers prepared for the International Uranium Symposium on the Pine Creek Geosyncline, held in Sydney June 1979, were published in the IAEA volume 'Uranium in the Pine Creek Geosyncline'. They described the regional geology of the Pine Creek Geosyncline, the geology of the Alligator Rivers uranium field, the geology and mineralisation of the South Alligator uranium field, a regional survey of metallic mineralisation in the Pine Creek Geosyncline, the evolution

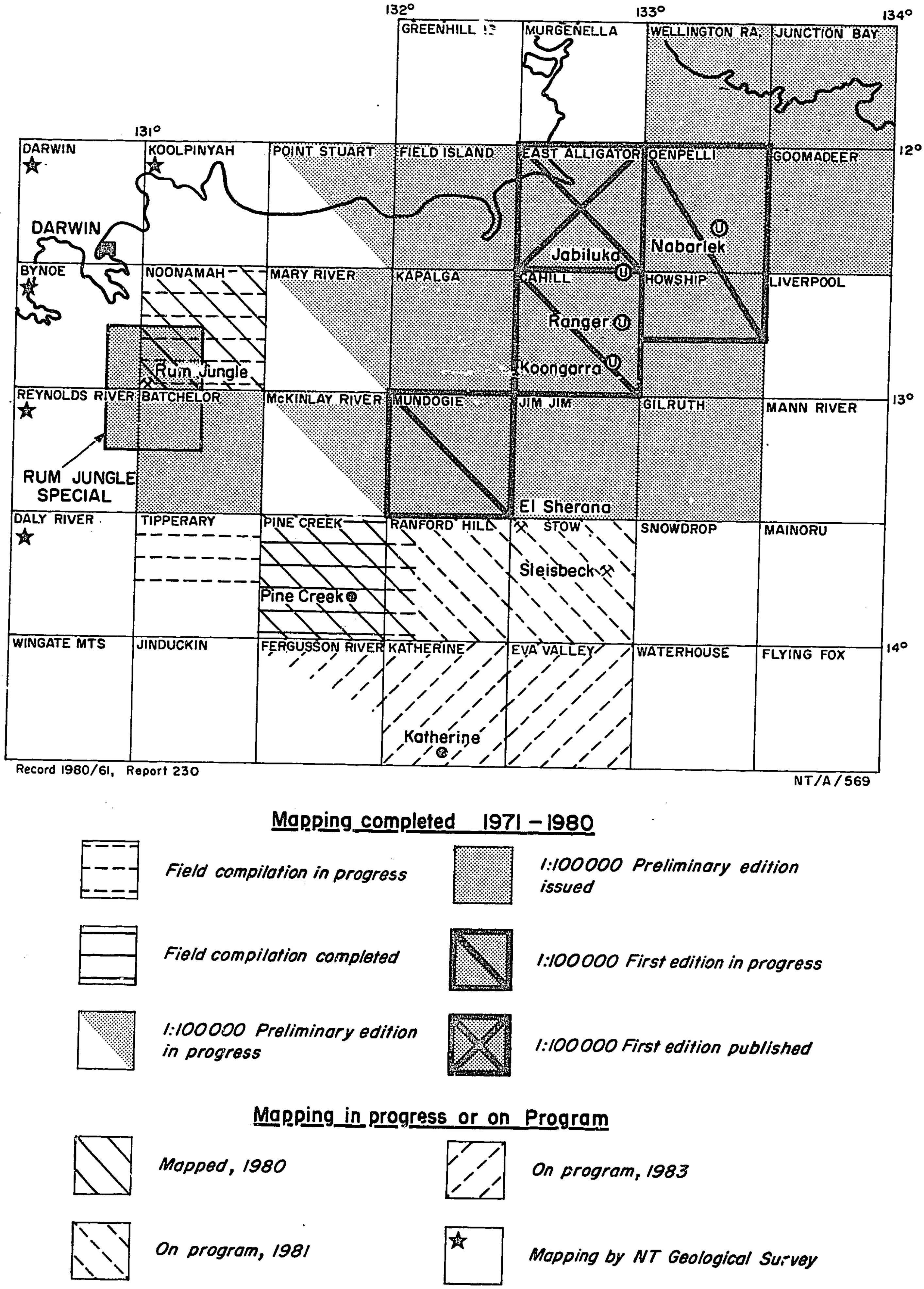


Fig. M3 Progress of geological mapping and index to 1:100000 Sheet areas, Pine Creek Geosyncline Project.

of the Pine Creek Geosyncline, evaporites and uranium mineralisation in the Pine Creek Geosyncline, and geochronology and evolution of the late Archaean basement and Proterozoic rocks in the Alligator Rivers uranium field.

A Professional Opinion describing the results of a reconnaissance of the Litchfield Complex in late 1979 was issued.

ALLIGATOR RIVERS URANIUM FIELD by R.S. Needham

Some key localities were revisited, photographed, and samples collected, especially exposures of the unconformable contact between the Kombolgie Formation and the Nanambu Complex. A courtesy visit was made to USGS geologists during their program of core logging and sampling at Jabiluka and Ranger 1. Needham led a brief excursion for some company geologists in the area and presented lectures on local and regional geology.

EAST ALLIGATOR and CAHILL were prepared for publication as 1st Edition maps (colour); extensive amendments were made to the Preliminary edition maps to incorporate company and AAEC exploration information, and data interpreted from 1975 colour photography. OENPELLI and the northern half of HOWSHIP were combined into a special map - the Geology of the Nabarlek Region - and prepared for 1st Edition. Commentaries were written for these 1st Edition maps. A Preliminary to the 2nd Edition 1:250 000 Alligator River map was prepared by generalising the six 1:100 000 Sheets covering the same area, and an Explanatory Note written. The map was forwarded for preparation to 2nd Edition (colour) following correction.

A Bulletin is in preparation.

RUM JUNGLE URANIUM FIELD by I.H. Crick

Revision of the RUM JUNGLE SPECIAL 1:25 000 compilation sheets was completed.

Fieldwork this year concentrated mainly on the northeast part (southwest part of NOONAMAH) of the RUM JUNGLE SPECIAL Sheet and on the Crater Formation. As proposed by French (1970*), an unconformity appears to separate the Crater Formation from underlying rocks. The Batchelor Group cannot therefore represent a continuous sedimentary sequence.

The Crater Formation is probably equivalent to the lithologically similar Mundogie Sandstone, which unconformably overlies the Stag Creek Volcanics and Masson Formation in the central region of the geosyncline. An

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* BMR Record 1970/65 (unpublished)

Table M1. Revised Lower Proterozoic stratigraphy of the Rum Jungle uranium field.

Revised stratigraphy	Needham & others, 1980*	Johnson, 1977**
FINNISS RIVER GROUP	FINNISS RIVER GROUP	FINNISS RIVER GROUP
Burrell Creek Fm	Burrell Creek Fm	Burrell Creek Fm
SOUTH ALLIGATOR GROUP	SOUTH ALLIGATOR GROUP	GOODPARLA GROUP
Mount Bonnie fm***	Kapalga Fm	Golden Dyke Fm., unit 8
Gerowie Tuff	Gerowie Tuff	unit 7
Koolpin Fm	Koolpin Fm	unit 6
MOUNT PARTRIDGE GROUP	MOUNT PARTRIDGE GROUP	
Wildman Siltstone	Wildman Siltstone	units 4 - 6
Mount Deane volcanics member***		units 5, 6
Acacia Gap Quartzite member***	Acacia Gap Sandstone	Masson Fm, Acacia Gap Tongue
	NAMOONA GROUP	
Whites fm***	Masson Fm	Golden Dyke Fm, units 1 - 4
	BATCHELOR GROUP	BATCHELOR GROUP
Coomalie Dolomite	Coomalie Dolomite	Coomalie Dolomite
Crater Formation	Crater Formation	Crater Formation
MANTON GROUP***		
Celia Dolomite	Celia Dolomite	Celia Dolomite
Beestons Fm	Beestons Fm	Beestons Fm

* In URANIUM IN THE PINE CREEK GEOSYNCLINE, IAEA, Vienna, 1-22.

** Geology of Rum Jungle 1:100 000 Preliminary Edition map.

*** Informal unit (Name in process of formalisation) earlier construction of the regional stratigraphy (Needham & others, 1980) correlated the Mundogie Sandstone with the Acacia Gap Sandstone, but as there is no evidence of an unconformable contact below the Acacia Gap Sandstone, the Mundogie/Crater correlation is preferred. The new correlation entails substantial stratigraphic revision in the Rum Jungle area (see Table M1).

A new unit, Whites formation (informal), has been proposed, to cover a transitional and variable sequence of sediments overlying the Coomalie Dolomite and within which the major Rum Jungle uranium and base-metal deposits are found.

SOUTH ALLIGATOR VALLEY URANIUM FIELD by D.A. Wallace

Those mines and prospects within MUNDOGIE were described, following literature research, and mine cross-sections and long-sections prepared for the Teagues/Rockhole/Sterrets line of workings. This information is being incorporated in the Record on the geology of MUNDOGIE (in press), pending completion of field research programmed for 1981 over the remainder of the uranium field.

PROTEROZOIC STRATIGRAPHY OF THE PINE CREEK GEOSYNCLINE

This project included field research in areas of Lower Proterozoic metasediments in PINE CREEK and the west of RANFORD HILL, and petrological, mineralogical, structural, and metamorphic studies of rocks from McKINLAY RIVER. These studies have largely confirmed and extended the stratigraphy defined in MUNDOGIE and MARY RIVER, but have indicated that the five-fold subdivision of Wildman Siltstone cannot be maintained.

PINE CREEK 1:100 000 SHEET AREA

Field research into Lower Proterozoic metasediments in PINE CREEK was completed during 1980. The area contains tightly to isoclinally folded north-trending Lower Proterozoic metasediments which are unconformably overlain by Adelaidean? Palaeozoic, Cretaceous, and Cainozoic sediments (Fig. M4). The metasediments are intruded by pre-orogenic Zamu Dolerite dykes and sills, three Carpentarian granites - the Cullen, Prices Springs, and McKinlay Granites - and by minor post-orogenic felsic dykes.

The stratigraphy established over recent years in other parts of the Pine Creek Geosyncline has been extended into the area, and the Cullen Granite has been divided into 13 phases within several coalesced plutons (Figs. M5).

The oldest rocks are a sequence of siltstone, quartz sandstone, carbonaceous phyllite, and calc-silicate marble northeast of Frances Creek. They are poorly exposed, intruded by Zamu Dolerite, and extensively hornfelsed by the Cullen Granite; their stratigraphic position below the Mundogie Sandstone suggests that they are probably Masson Formation.

Sandstone, arkose, minor conglomerate, phyllite, and siltstone of the Mundogie Sandstone form rugged strike ridges rising to 300 m west of the low rubbly outcrops of the Masson Formation. Farther west the Mundogie Sandstone is conformably overlain by the Wildman Siltstone; this has been divided into a lower laminated pyritic carbonaceous shale and siltstone unit which is characteristically red and white colour-banded in places, and an upper siltstone and phyllite unit with interbeds of fine to medium quartz sandstone.

Remnants of the massive hematite lodes of the abandoned Frances Creek iron mine are fault breccias in oxidised pyritic carbonaceous phyllite of the lower unit of the Wildman Siltstone. The fault breccias are stratabound and possibly formed by thrusting during the Early Proterozoic before the major folding episode. The iron lodes are unconformably overlain by flat-lying Cretaceous sandstone and conglomerate of the Petrel Formation, indicating that the orebodies are pre-Cretaceous. The orebodies formed probably by oxidation of pyritic carbonaceous shale in the fault breccias.

The South Alligator Group unconformably overlies the Wildman Siltstone east of the McKinlay River, and forms a complexly folded antiform in the Burrundie area west of the Stuart Highway. In both areas the three formations within the Group (the Koolpin Formation, Gerowie Tuff, and Mount Bonnie formation) are well exposed and contain the same rock types as elsewhere in the

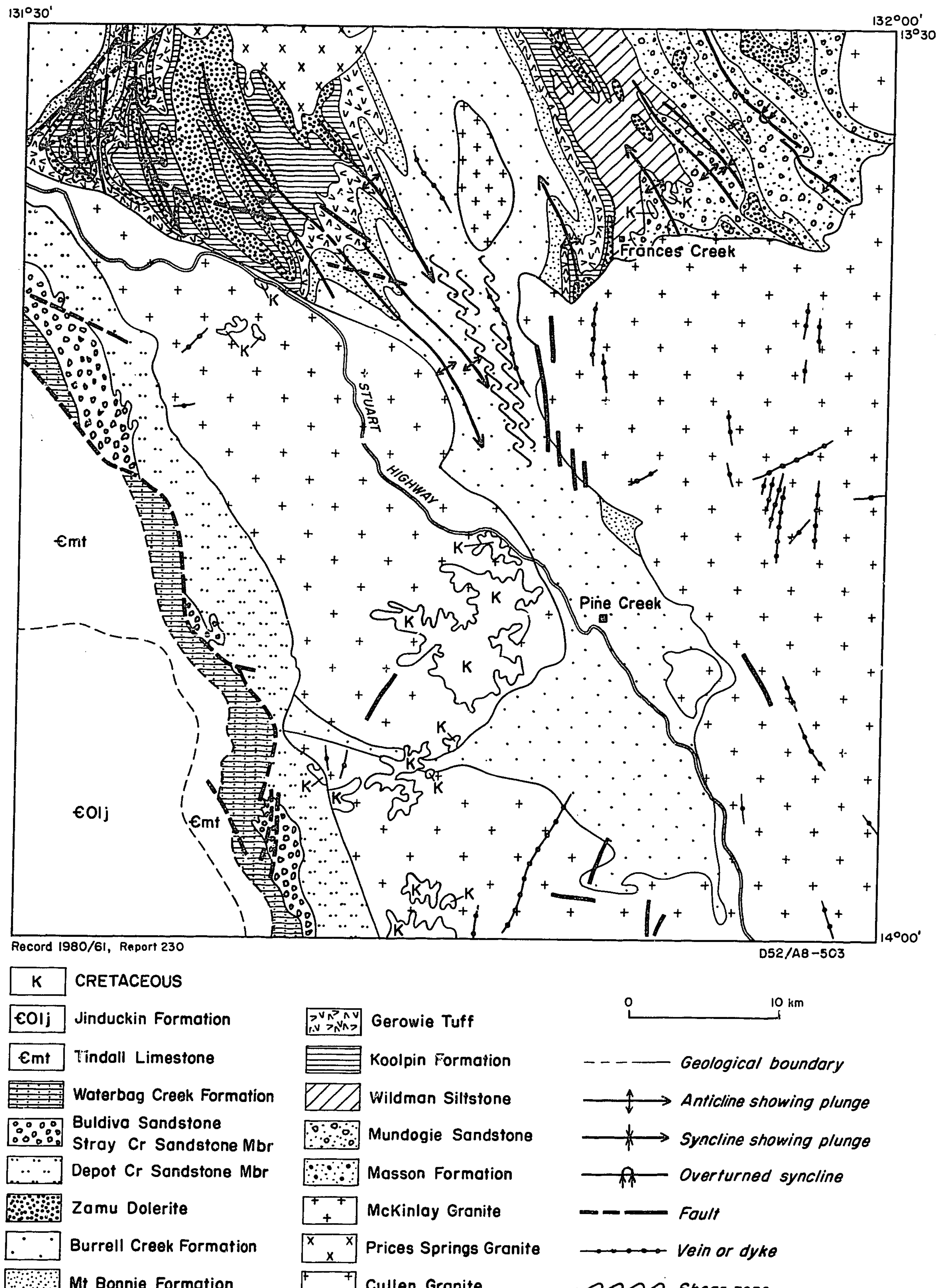

Fig. M4 Solid geology, Pine Creek 1:100000 Sheet area, Pine Creek Geosyncline.

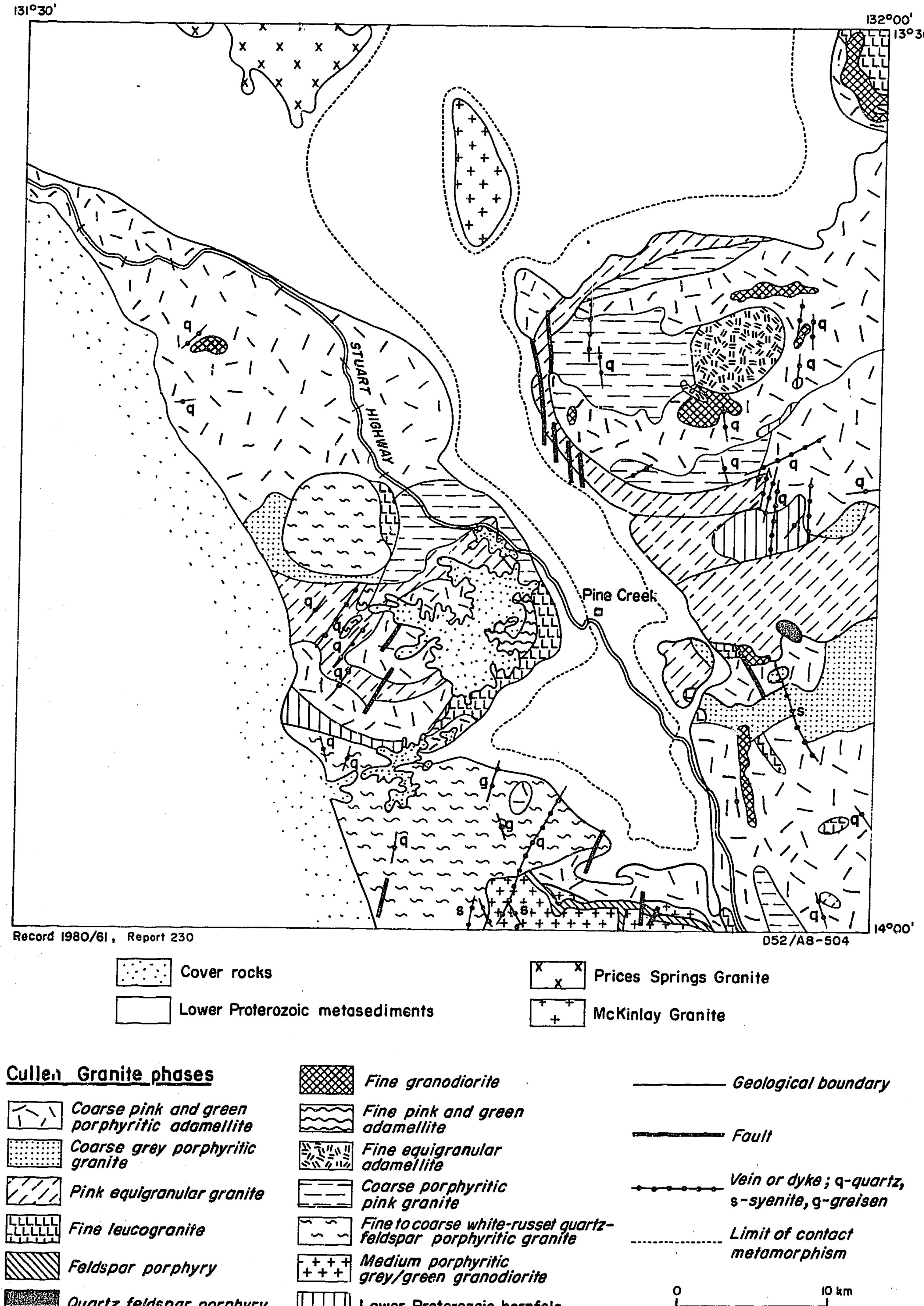

Fig. M5 Phases of the Cullen Granite

Pine Creek Geosyncline. However, those in the Burrundie area are extensively hornfelsed by the Cullen and Prices Springs Granites (up to 5 km from the granite contact), and have been intruded by three major sills of Zamu Dolerite averaging 100 m thick. East of the McKinlay River only one sill is present, within the Koolpin Formation. The thickness of the formations differs slightly, and is greatest near Frances Creek (Koolpin Formation 300 m, Gerowie Tuff 500 m, Mount Bonnie formation 800 m).

A narrow belt of hornfelsed carbonaceous shale, argillite and devitrified tuff crops out against the Cullen Granite 7 km north of Pine Creek. The metasediments, previously included in the Burrell Creek Formation, are part of the Mount Bonnie formation.

In the centre of the area the Burrell Creek Formation forms a north-trending belt about 8 km wide between two lobes of the Cullen Granite. It is the youngest and most extensive Lower Proterzoic unit and consists of an indeterminate thickness of phyllite, fine to medium greywacke, minor conglomerate, and volcanics. The rocks are tightly folded about shallow south-trending axes, well cleaved, and extensively hornfelsed by the Cullen Granite. The hornfels zone is commonly marked by prominent ridges up to 2 km wide paralleling the granite contact, whereas recrystallised greywacke forming an outer zone about 500 m wide grades into lower greenschist facies sediments in low undulating terrain. Banding, made up of alternating fine and spotted layers up to 4 cm thick, reflects original compositional banding in the inner zone.

Adelaidean and younger sediments

The Buldiva Sandstone of the Tolmer Group forms a plateau along the western edge of PINE CREEK. The formation consists of 900 m of interbedded sandstone, siltstone, and minor shale and volcanics which dip 11° to the southwest.

The Depot Creek Sandstone Member forms the base of the formation and unconformably overlies the Cullen Granite and the Burrell Creek Formation. It consists of about 450 m of fine to coarse pink massive quartz sandstone which is in places poorly sorted and pebbly. Ripple marks and cross-beds are common and indicate current directions from north to northeast.

The Stray Creek Sandstone Member conformably overlies the Depot Creek Sandstone Member and contains micaceous sandy siltstone, shale, and very fine quartzite. North of the Douglas River the member is about 450 m thick and contains a 25 m thick, previously unrecorded volcanic unit about 340 m above the base. The volcanics are very ferruginous and opaline altered rocks and fine pink tuffs. South of the Douglas River only the lowest 150 m of the member is exposed. A chert breccia is commonly present at this contact, below mottled ferruginous medium to coarse quartz sandstone, minor grit, and silicified calcarenite of the Waterbag Creek Formation. The contact has not been found exposed but locally appears unconformable and is faulted in many places. The Waterbag Creek Formation forms craggy hills around the margin of the Daly River Basin and appears to conformably underlie the lower Palaeozoic Daly River Basin sequence. The formation has previously been assigned to the Adelaidean Tolmer Group, but its apparent contact relation suggest that it may be Cambrian.

An interbedded sequence of fine to medium crystalline limestone with minor chert bands, lenses, and nodules, fine friable quartz sandstone commonly with manganese dendrites, sandy limestone, and marl above the Waterbag Creek Formation was mapped as Tindall Limestone by Walpole & others (1968)* and described as 'mainly fine-grained and coarsely crystalline limestone with some lenses of sandstone and siltstone'. The sequence in PINE CREEK consists of at least 50 percent sandstone and marl. The fossil fauna described by Walpole & others in the Tindall Limestone for areas farther south and west is not apparent in PINE CREEK, although stromatolites were found at Limestone Hill, in the southwest of the area.

Medium to coarse red-brown friable quartz sandstone with interbedded medium pink and grey crystalline limestone and marl overlies the Tindall Limestone near Limestone Hill and may be Jinduckin Formation. Yellow-grey fine oolitic limestone 6 km southwest of Limestone Hill may be part of the same sequence and indicates a very shallow environment of deposition.

Extensive Cainozoic cover, mainly laterite and gravelly sandy soil, mask much of the Daly River Basin sediments. Low dips, vague bedding trends, and prominent photolinears suggestive of faulting hinder the interpretation of formation boundaries and relation between units.

McKINLAY RIVER 1:100 000 SHEET AREA by D.A. Wallace, P.G. Stuart-Smith, R.S. Needham, M.J. Roarty.

In the light of 1980 research in PINE CREEK, the provisional five-fold subdivision of the Wildman Siltstone advanced in last year's Geological Branch Annual Summary of Activities has been amended. The lower three units are now

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*BMR Bulletin 82.

correlated with either the Mundogie Sandstone or the Masson Formation, and the two upper units are the same as the upper and lower units of the Wildman Siltstone recognised in PINE CREEK and described in the previous section.

NOONAMAH 1:100 000 SHEET AREA by I.H. Crick, E. Dwyer

Fieldwork should be completed before the 1980/81 wet season. Compilation is being undertaken by the Geological Survey of the Northern Territory (GSNT) and final map production by BMR.

In the southwest, which covers part of the Rum Jungle uranium field (see earlier section), the Archaean Rum Jungle Complex is overlain unconformably by a complete succession of Lower Proterozoic rocks of the Manton (informal), Mount Partridge, South Alligator and Finniss River Groups (see Table M1). The southeast is dominated by tightly to isoclinally folded sediments of the Finniss River and South Alligator Groups. The northern half is mainly covered by unconsolidated Cainozoic sediments. Poorly consolidated sandstone of the Cretaceous Petrel Formation, and quartz breccia - probably basal breccia of the Depot Creek Sandstone Member of the Buldiva Sandstone - form scattered outcrops. In the northwest, tightly folded resistant ridges of quartzite containing pyrite casts near Noonamah are correlated with the Acacia Gap Quartzite member (informal). Near Berry Springs, banded siltstones and minor volcanics of the Wildman Siltstone, ironstone of the Koolpin Formation, and fine silicified tuff of the Gerowie Tuff are present. The Koolpin Formation here is very thin (~20 m) and may indicate condensing of all or part of the South Alligator Group, or local unconformity at the base of the Gerowie Tuff. Drilling of this sequence in 1981 is planned by GSNT.

BATCHELOR-TIPPERARY 1:100 000 SHEET AREAS by I.H. Crick

The BATCHELOR Preliminary map has been revised to incorporate the new stratigraphy (see Table M1.) and is due for publication in 1981. Compilation of areas of Precambrian rocks in TIPPERARY is in progress and will be published as a special map combined with BATCHELOR. Mapping and compilation of Palaeozoic rocks in TIPPERARY, a joint project with GSNT, has been removed from the program.

GEOLOGY AND MINERALISATION OF THE CULLEN MINERAL FIELD by P.G. Stuart-Smith, D.A. Wallace, R.S. Needham

The Cullen mineral field contains most of the base and precious metal occurrences in the Pine Creek Geosyncline. Many of the occurrences are hydrothermal and associated with intrusion of the Cullen Granite complex, or are the product of remobilisation of metals from the country rock at or about the time of granite intrusion. This study is designed to investigate the nature of mineralisation and its genesis by study of the mineral occurrences, their host rocks, and the granite complex. During the year the granites of PINE CREEK and RANFORD HILL were studied, mines and mineral occurrences of PINE CREEK examined, and collation of information from company and government reports on mining and exploration in the mineral field began.

A wide range of granite types in the Cullen batholith indicates the presence of several coalesced plutons, and in places screens of hornfelsed metasediment lie along these contacts (Figure M5.) Geochemical study of the granite phases, alteration and griesen zones, and late dyke rocks may reveal the source of some of the metals in the mineral field.

The Cullen Granite batholith has a broad V-shaped outcrop which covers over half of PINE CREEK and the wetern part of RANFORD HILL. The granite intrudes the Lower Proterozoic metasediments which are extensively hornfelsed up to several kilometres from the contact.

Several more phases than the five previously recognised were delineated and include the following:

a) coarse porphyritic pink and green adamellite
b) coarse grey porphyritic granite
c) coarse equigranular pink granite
d) fine to medium leucocratic granite
e) coarse porphyritic pink and green mesocratic granite
f) felsite
g) grey quartz-feldspar porphyry
h) fine grey tonalite
i) fine porphyritic pink and green adamellite
j) medium equigranular pink and green adamellite
k) coarse porphyritic pink granite
l) fine to coarse slightly porphyritic grey quartz-feldspar granite
m) medium porphyritic grey-green granodiorite

Relative ages of phases can be established in some areas. Fine dark grey tonalite is the oldest, and occurs as xenoliths or rafts up to several kilometres long within coarse porphyritic adamellite. Adamellite, equigranular pink granite, and porphyritic granite phases form concentrically zoned plutons west of and northeast of Pine Creek, and appear to be transitional and cogenetic. Fine leucogranite is the youngest phase and commonly forms dykes or small stocks containing numerous xenoliths and rafts of the other phases.

Numerous quartz reefs, quartz-feldspar porphyry, and fine-grained felsic and mafic rocks commonly form elongate bodies or northerly and westerly trending dykes within the batholith. North-trending alteration zones of greisen and albitite cut several granite phases southeast and southwest of Pine Creek. Bodies of hornfels - predominantly cordierite-andalusite-biotite-quartz hornfels and less commonly chiastolite-bearing carbonaceous hornfels, pyritic calc-silicate hornfels, and quartzite - form rafts up to one kilometre across or 'screens' along the margins of some plutons.

EARLY PROTEROZOIC EVAPORITES AND URANIUM MINERALISATION IN THE PINE CREEK GEOSYNCLINE by I.H. Crick

Detailed studies of Lower Proterozoic carbonates of the Pine Creek Geosyncline have shown that most contain substantial amounts of evaporite pseudomorphs. The carbonates are closely associated with the major uranium deposits in the Rum Jungle and Alligator Rivers uranium fields. It has been proposed by Crick & Muir (1980)* that the formation of these deposits is closely linked to the complex history of the carbonates. This project aims to elucidate in more detail the depositional, diagenetic and replacement history of the evaporites and their influence upon uranium ore genesis.

Coomalie Dolomite carbonate samples obtained from Geopeko drill core near Woodcutters Prospect in the Rum Jungle uranium field were examined by petrological, electron probe, and cathode luminescence techniques. Randomly orientated discoidal gypsum pseudomorphs (now magnesite) of various sizes in a fine-grained carbonaceous, high-magnesium chloritic matrix are common but have not been previously described. The carbonaceous matrix also contains minor disseminated fine-grained calcium phosphate, which suggests that the sub-economic phosphate deposits formed over the Coomalie Dolomite at Castlemaine Hill near Batchelor were derived from this formation.

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*In URANIUM IN THE PINE CREEK GEOSYNCLINE. IAEA, Vienna, 531-42.

Gypsum and possible halite 'ghost crystal' pseudomorphs were observed in medium-grained equigranular dolomite from Whites and Intermediate open cuts, and show that not all evaporite pseudomorphs are restricted to magnesite in this area.

Sixty carbonate samples from drill core obtained from the Ranger 3 deposit were collected and sent for thin sectioning.

GAMMA-RAY SPECTROMETRY OF THE RUM JUNGLE, WATERHOUSE, AND LITCHFIELD COMPLEX GRANITES by I.H. Crick

The aim of this project is to gain additional data on U, Th, and K values of these granites and to compare the results with geochemical analyses from these and other granites in the Pine Creek Geosyncline in order to:

(1) test the techniques, and

(2) see if the Litchfield granites can be differentiated from other granites in the Pine Creek Geosyncline by this technique.

About forty readings from eleven different sites were obtained. The data require further processing before any comment can be made.

ANTARCTICA

by

R.J. Tingey

STAFF: R.J. Tingey, J.W. Sheraton, L.P. Black (part-time), E.M. Truswell, D. Wyborn, (Sedimentary Section), P.R. James (University of Adelaide).

INTRODUCTION

BMR geological investigations in Antarctica are part of an on-going BMR commitment to ANARE research programs; this commitment dates from the 1950s, and is consistent with the basic functions of BMR. The rationale for this commitment was spelled out in the 1978 Geological Branch Annual Summary of Activities.

Since 1975, BMR fieldwork and related office and laboratory studies have concentrated mainly on Enderby Land, on the western edge of Australian Antarctic Territory; university scientists began collaborative studies in 1978 with BMR encouragement and assistance. No fieldwork was done in the 1978-79 austral summer but the program originally proposed for that season was successfully undertaken in the 1979-80 season. Only one BMR geologist, Black, was involved and he collected samples for geochronology study as part of a collaborative project with Dr P.R. James of Adelaide University. Black described his geochronological studies elsewhere and James presented an account at the Second International Archaean Symposium in Perth, Western Australia in May 1980. In addition, D. Wyborn participated in GANOVEX 79, the West German expedition to north Victoria Land as the Australian visiting scientist. His participation and the methods of fieldwork adopted arose in part from discussions that Tingey held with scientists at the Federal German Bundesanstalt fur Geowissenschaften und Rohstoffe in Hannover in 1978.

The comparatively modest level of BMR geological field activity in Antarctica in 1979-80 has allowed the completion of certain publications and significant progress with laboratory studies and map compilations. Of the BMR geologists collaborating on Antarctic studies, Tingey has also been involved in Yilgarn work, Sheraton had an extensive period on sick leave, and both Black's and Wyborn's involved on Antarctic studies on a part-time basis only. Sheraton's and Black's studies are described under the Petrological Laboratory and Geochronological Laboratory reports, and Wyborn's are described in the Sedimentary Section report; E.M. Truswell has reported on her Antarctic studies in the Palaeontological Group report.

This report is mainly concerned with 1) regional geological studies; 2) the progress of publications; 3) Gaussberg; and 4) other activities.

REGIONAL GEOLOGICAL STUDIES by R.J. Tingey

In the past 12 years, BMR geologists have undertaken regional studies in the western part of Australian Antarctic Territory specifically in the Prince Charles Mountains and Enderby Land. The intention has been to map these areas at 1:250 000 scale and to record each season's activities on a locality by locality basis in a BMR Record in order to provide a coherent account of the highly expensive field operations co-ordinated and supported by the Antarctic Division of the Department of Science and the Environment. The Records and maps may then be used as an information base for future research and for publications. Although publications and maps have generally proceeded satisfactorily, a backlog of Records has arisen virtually because of the annual commitment to fieldwork, the part-time involvement of BMR geologists in Antarctic research, and the amount of data that arise from the efficient ANARE summer field operations. In particular, Records for the 1968-69 and 1972-73 seasons in the Prince Charles Mountains and for the 1976-1977 season in Enderby Land are outstanding.

During the year significant progress was made towards completing the two Records relating to the Prince Charles Mountains. Completion of the 1968-69 Record was deemed desirable because new fieldwork in the area covered then is likely in the forthcoming 1980-81 summer field season. In 1968-69, operations were based at Landing Bluff in the northeast corner of the Amery Ice Shelf and extended from the Vestfold Hills in the north of Prydz Bay along the east side of the Amery Ice Shelf, and into the Northern Prince Charles Mountains; the Prydz Bay area is likely to be revisited in the near future.

The 1972-73 season was mainly concerned with geological mapping of the Prince Charles Mountains, and its results formed the basis for the regional geological interpretation presented by Tingey (in press)*. In this interpretation the importance of basic dykes as time stratigraphic markers in Antarctic Precambrian rocks was stressed. Basic dykes have also been used to discriminate between the older Napier Complex in Enderby Land, which is intersected by basic dykes, and the neighbouring younger Rayner Complex, where there are no basic dykes. Similar reasoning applied to data from the 1968-69 season in the Amery Ice Shelf area suggest that older, possibly Archaean, metamorphic rocks may occur at Jetty Peninsula, near Beaver Lake in the Prince Charles Mountains.

Progress was also made with compilation of 1:500 000 scale geological maps of the Prince Charles Mountains, and the Southern Prince Charles Mountains Sheet should be edited in October 1980. These maps are being drawn on a base compilation of LANDSAT imagery as has been previously done for remote arid areas such as the Yemen, Saudi Arabia, and the Tibesti Massif in Africa. In these low -latitude areas, sun elevation on the Landsat imagery changes very little from season to season and it is not difficult to tone-match imagery acquired on different dates; in Antartica, sun elevation on Landsat imagery ranges from 0° to 35°, resulting in differences in shadows and tones from rock outcrops from day to day. In addition, in the Band 7 Multispectral Scanner (MSS) imagery provided by the Division of National Mapping, bare ice areas in places give much the same tones on Landsat photographic products as do rock outcrops. In drawing Antarctic geological maps on Landsat bases there are thus extra problems particularly in the tonal matching of image scenes acquired on different dates, and in the distinction of rock outcrops from bare ice areas. However, the use of LANDSAT base maps does give map users a graphic synoptic overview of the mapped landscape and thus some appreciation of field conditions.

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*In Craddock, C.C. (Editor) - ANTARCTIC GEOSCIENCE. University of Wisconsin Press.

In Enderby Land, geological map compilation has yet to start, and 1:250 000 scale LANDSAT base maps are being prepared. Other Enderby Land studies are described elsewhere in the summaries of Black and Sheraton, but a Record of the 1976-77 season's fieldwork is still outstanding although it has been pre-empted to a certain extend by the publications on Enderby Land noted below.

Publications

The abstracts of the 1979 Workshop on Antarctic Geology were published in volume 26 of the Journal of the Geological Society of Australia (Tingey, 1979), and provide an overview of Australia's Earth-science research effort. During 1980, Tingey collaborated with P. Wellman in preparing a manuscript for publication which describes isostatic uplift effects in the Prince Charles Mountains; the uplift has resulted from the removal by glacial erosion of more than 1 km of rock from parts of the Lambert Glacier basin (Wellman & Tingey, in prep.). This paper, for which geophysical, topographic, and glaciological data from the Lambert Glacier basin were studied, concludes that locally almost 0.8 km uplift has taken place and that more would occur if the present ice load were removed. Remnants of a preglaciation erosion surface exposed in the Prince Charles Mountains provide a convenient marker against which to measure the levels of the present ice surface, the present regional rock surface, and the various uplift effects.

A comprehensive description of the geology of Enderby Land was published in volume 27 of the Journal of the Geological Society of Australia (Sheraton & others, 1980), and so was a discussion of alkaline dyke rocks from both Enderby Land and the Prince Charles Mountains (Sheraton & England, 1980). Aspects of the metamorphic geology of the sapphirine-quartz and osumilite-bearing metapelites of Enderby Land were discussed by Ellis & others (1980) in volume 72 of Contributions to Mineralogy and Petrology, and Ellis is preparing a further publication on metabasic rocks in the Napier Complex.

GAUSSBERG by R.J. Tingey

During the year Sheraton & Cundari (1980)* published an account of the petrology of Gaussberg, a 370 m high isolated leucite basalt volcanic cone on the Antarctic coast at 90°E which was visited by BMR geologists in 1977. The age of Gaussberg has been the subject of some debate: Imperial German geologists deduced a Pliocene age as a result of observations made in 1901 and Soviet

* Contributions to Mineralogy and Petrology, 71, 417-27.

geologists publishing K-Ar dates of 20 m.y. and 9 m.y. in the 1960s and 1970s. Fission track studies on glass from the Gaussberg lavas have yielded an imprecise age, based on very few tracks, of 25 000 ± 12 000, years and this order of age has been confirmed by K-Ar analyses of leucite crystals separated from the lavas which have yielded ages of 60 000 and 53 000 years (I. McDougall, personal communication, 1980). Special care was taken to avoid possible contamination by xenolith material that is thought to have occurred in the dating of hominid remains in east Africa.

Observations that glacial striae and erratics of gneissic continental rocks occur up to the summit of Gaussberg led the original German workers to infer a preglacial or Pliocene age for Gaussberg. Since then the Antarctic ice sheet has been shown to have existed at least from mid-Miocene times, and the young ages now obtained from the Gaussberg rocks provide a time constraint on some of the fluctuations in the level of the Antarctic ice sheet in the Gaussberg region. Glaciological studies in this region have led glaciologists to infer that the ice sheet may have surged, a process that could have had dramatic consequences for global climate.

OTHER ANTARCTIC ACTIVITIES by R.J. Tingey

In March 1980 the Minister for Science and the Environment presented to Parliament the initial report to Government of the Antarctic Research Policy Advisory Committee (ARPAC). In his tabling statement the Minister announced the appointment of 'a Planning Committee of scientists to assess Antarctic Research proposals by government agencies, universities and colleges, and industry'. The planning committee consists of co-ordinators in various disciplines and Tingey was nominated as the Co-ordinator for the Marine and Terrestrial Earth Sciences, a broad group of activities that have obvious relevance to a major objective of Australia's Antarctica research program-namely, research directed towards the living and mineral resources (of Antarctica) and the environmental effects of their exploitation.

In this capacity, Tingey has been asked to assess proposals for an onshore geology program in the 1980-81 season and to consider 23 proposals for marine and terrestrial Earth-science research for 1981-82 and beyond. He has also continued his commitment to the *ANCAR Sub-Committee for Geology but resigned from ANCAR itself on the expiry of his term of office. As Australian member, Tingey was represented at the July 1980 meeting of the **SCAR Working Group on Geology in Paris by Dr E.M. Trusswell; he prepared a report on recent Australian geological research in Antarctica for this gathering.

YILGARN PROJECT

by

A.J. Stewart

STAFF: A.J. Stewart, R.J. Tingey, L.A. Offe (all part-time)

The Yilgarn Project is jointly conducted by BMR and the Geological Survey of Western Australia (GSWA), and forms part of a program of field research and regional mapping of Western Australia at 1:250 000 scale. The work is designed to provide basic data on the stratigraphy, lithology, structure, and geological evolution of the Sandstone and Youanmi (Fig. M6) Sheet areas in the northern part of the Archaean Yilgarn Block, for use in mineral and groundwater resource assessment (Fig. M7) and prospecting, and to contribute to BMR's understanding of Australian geology.

Fieldwork in Sandstone and Youanmi was completed in September 1979. Since then, Youanmi has been compiled, drawn and forwarded to GSWA for comment. Sandstone is in the process of drafting. Reports on the two areas are to take the form of detailed Explanatory Notes, and initially will be issued as BMR Records to accompany the Preliminary Editions of the maps. The first draft of the Youanmi Notes is about 60 percent complete: the Sandstone Notes are not yet started.

In common with other Archaean terrains, the Yilgarn Block comprises synformal greenstone belts of weakly metamorphosed mafic igneous rocks and subordinate sediments, intruded by or faulted against voluminous granitoid masses. A third unit, of various gneisses, crops out as elongate zones adjacent to the greenstone belts, and also forms enclaves in the granitoids. The origin of these gneisses is much debated. Some believe them to be a pre-greenstone basement, and hence the oldest rocks in the region; others believe they are the deformed margins of the post-greenstone granitoid intrusions. Field and petrographic study of the gneisses in Youanmi has indicated that, whereas they

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* ANCAR - Australian National Committee for Antarctic Research, Australia. Academy of Science.

** SCAR - Scientific Committee on Antarctic Research of the International Council of Scientific Unions.

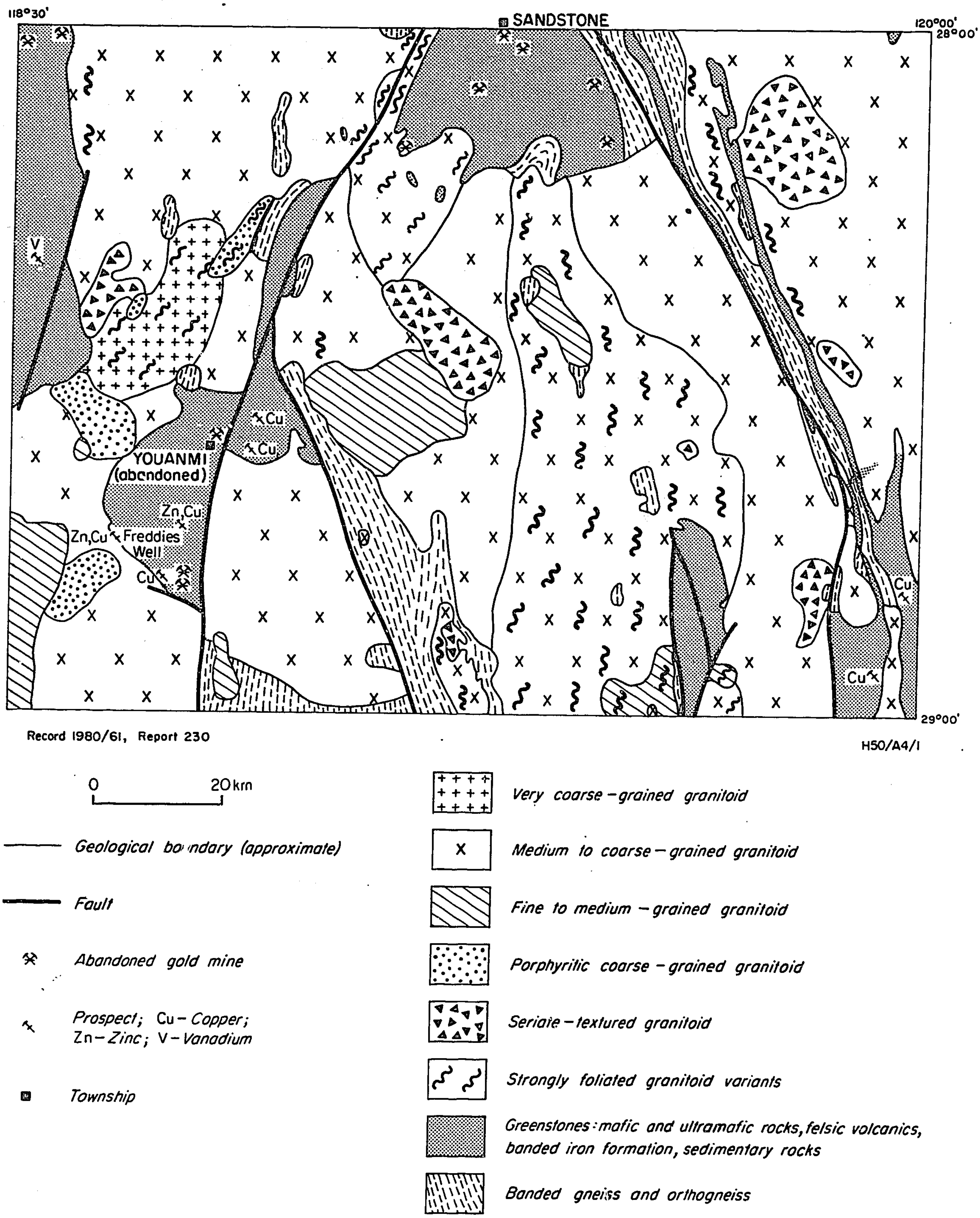

Fig. M6 Solid geology of Youanmi 1:250 000 Sheet area, W.A.

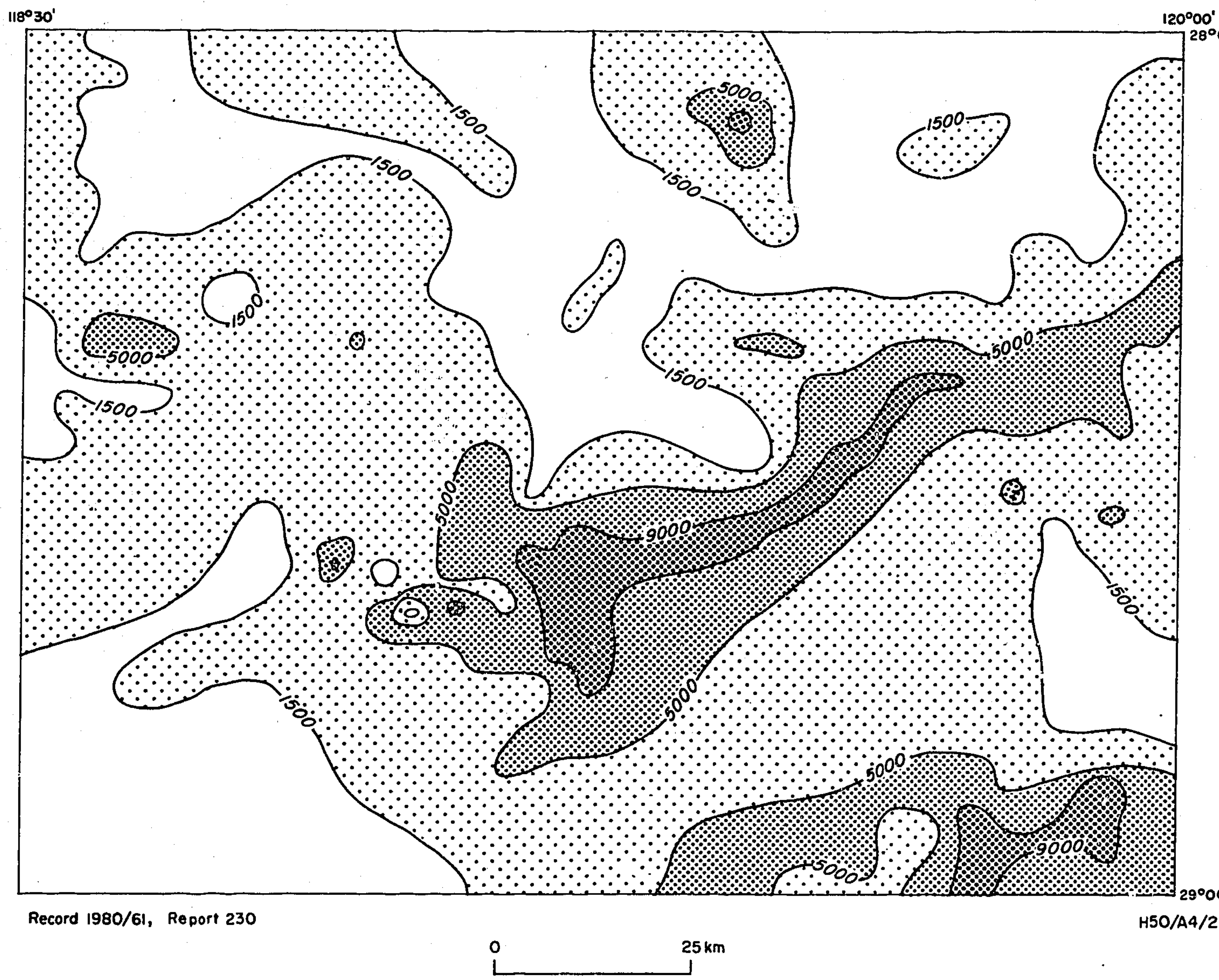

Fig. M7 Groundwater salinity map of Youanmi 1:250 000 Sheet area, showing generalised salinity contours in parts per million of dissolved solids, derived from salinity measurements during 1979 field season.

consist mostly of interlayered tonalite, granodiorite, adamellite, and granite, they also include abundant layers and pods of other rocks, such as quartzose gneiss, amphibolite, mafic calc-silicate rock, banded iron formation, and ultramafic schist. Furthermore, they show a complex history of an earlier progressive metamorphism to middle or upper amphibolite facies, followed by later reheating to greenschist facies, which caused partial retrogression of the higher-grade assemblage. The greenstones, in contrast, show only the effects of the greenschist metamorphism. The overall composition of the gneisses, namely, layered granitoids with subordinate metasediments and mafic to ultramafic igneous rocks is consistent with an origin either as the deformed marginal parts of granitoid masses which intruded lit-par-lit into the greenstone belts, or as a separate unit of mainly arkosic sediments with subordinate calcarous rocks, banded iron formation, and mafic to ultramafic sills and flows. The polymetamorphic character of the gneisses, however, and their occurrence as enclaves in the granitoid masses are more easily explained by their being a unit older than the greenstones.

Metalliferous deposits in Sandstone and Youanmi include copper, zinc, vanadium, gold, and uranium. Copper and zinc occur in several prospects; these have been investigated by exploration companies, and found to be uneconomic at the present time. The most promising prospect is located near Freddies Well in the southwest of Youanmi (Fig. M6). The metalliferous horizon here is a peculiar quartzite colloquially known as 'freddite', which is interbedded with metamorphosed felsic volcanics and consists of round bleb-like grains of blue rutilated quartz in a matrix of sphalerite and chalcopyrite. The 'freddite' is transitional into, and is a facies variant of banded iron formation, and may have formed as an exhalative product on the flank of a rhyolite volcano. Vanadium occurs in magnetite and ilmenite which crystallised in gabbro lopoliths into seams several metres thick. The deposits are too remote from markets to be currently economic. Gold is being actively sought and won mainly in alluvial areas, but small-scale underground mining continues near Barrambie in Sandstone. Uranium occurs extensively in the sediments filling the present salt lakes, and in the drainage channels leading to the lakes. Only the Yeelirrie deposit in the northeast of Sandstone is sufficiently concentrated to be economic.

GEOLOGICAL INVESTIGATIONS IN QUEENSLAND AND PAPUA NEW GUINEA

Supervising Geologist: G.M. Derrick

MOUNT ISA-LAWN HILL PROJECT

by

G.M. Derrick & I.H. Wilson (GSQ)

STAFF: BMR: G.M. Derrick (Project leader); I.P. Sweet; L.A. Wyborn(granites); R.W. Page (geochronology); P.A. Scott (stream-sediment geochemistry); I. Hone (geophysics); J. Stirzaker, A. Retter, J. Gallagher, D. Green, G. Butterworth (draftsmen).

GSQ: I.H. Wilson, L.J. Hutton

AIMS: Research of the Precambrian rocks of the Mount Isa inlier at a scale of 1:100 000, in order to delineate areas potentially favourable for mineralisation, to revise the stratigraphy and structure, and to reconstruct the sedimentary, igneous, and metamorphic history of the region.

The project is scheduled for completion by December, 1981.

RELATED INVESTIGATIONS: Geochronology, geochemistry, and granite studies (see Metalliferous Laboratory reports); geophysics of the Mount Isa region (see Geophysical Branch report); Duchess geology.

FIELD ACTIVITIES

Introduction

Field research in 1980 was directed to the examination of geological anomalies or problems throughout the inlier, before final compilation of maps and reports. Areas re-examined included areas of Leichhardt-Metamorphics and migmatite in the Wonga belt, where Mary Kathleen Group-Argylla Formation contacts have been subject to high strain and high-grade metamorphism; the Tommy Creek area, where U-Pb zircon ages of about 1610 m.y. recorded from microgranite and rhyolite (see Page, Geochronology Laboratory report, this volume) suggest a volcanic/sedimentary/plutonic episode younger than the Mount Isa and McNamara Groups, presently regarded as the youngest group of rocks in the Mount Isa

Inlier; and the Lawn Hill area, where a large circular structure in Cambrian and Precambrian rocks was investigated for evidence of cryptoexplosion or other origins.

Kalkadoon-Leichhardt Block

Samples of grey recrystallised dacitic to rhyolitic volcanics were collected from the type section of the Leichhardt Metamorphics, to supplement the existing geochemical characterisation data file used in regional crustal studies. Areas of metadacite are progressively recrystallised to foliated tonalite or diorite near Kalkadoon Granite; migmatite zones near the granite consist of grey gneissic tonalite, and diorite and adamellite, cut by thin bands of ptygmatically-folded aplite and granite. This zone is interpreted as migmatised equivalent of the Leichhardt Metamorphics.

New U-Pb zircon data on Leichhardt Metamorphics are discussed elsewhere (see Page, Geochronology Laboratory report, this volume).

Wonga belt

Contact relations. Contacts between Mary Kathleen Group (Ballara Quartzite, Corella Formation) and Argylla Formation were examined at many localities between Mary Kathleen in the south and Kajabbi in the north.

The Argylla Formation contains flow-banded acid metavolcanics, (some spherulitic), one or two thin quartzite and minor calcareous labile quartzite interbeds, minor pebble and cobble conglomerate, and, at or near the top, psammitic schist of sedimentary origin. The metavolcanics are intensely folded on the west limb of the Rosebud Syncline, and become strongly foliated and gneissic eastwards towards the Wonga Granite. Rolled quartz pebbles in conglomerate are also evidence of strong deformation and high strain.

This sequence is overlain by pebbly arkose in places, but more commonly by coarse-grained glassy quartzite, locally ferruginous, considered to be the Ballara Quartzite; magnetite in the quartzite reflects erosion of the underlying magnetite-bearing metavolcanics. The quartzite is overlain by calc-silicate granofels with interlayered para-amphibolite, cordierite granofels, and psammitic schist. Locally the quarzite is absent, and the calc-silicate rocks rest directly on underlying felsic gneissic rocks and schist. Throughout most of the Wonga belt the basal quartzite/calc-silicate sequence and underlying gneissic and schistose rocks are cut by pegmatite.

All rocks in the contact zone are concordant. The contact is interpreted on regional grounds as being a disconformity between younger shallow water quartzite and laminated calcareous rocks and an older sediment-bearing volcanic sequence.

Correlations. Blake (1980)* presents the view that the Corella Formation east of the Wonga belt is older than the Corella Formation west of it.

Facing in the Ballara Quartzite in the Rosebud Syncline west of the Wonga belt, and in the Ballara Quartzite east of the Wonga belt in QUAMBY confirm that in both areas quartzite and calc-silicate rocks overlie the gneissic and schistose rocks mapped as Argylla Formation. Further work south of Lake Corella near the Secret mine showed that the Ballara Quartzite in the Rosebud Syncline can be traced almost continuously through a subsidiary south-plunging syncline and anticline eastwards to the Mary Kathleen Syncline; i.e., there is essential stratigraphic (and metamorphic) continuity between Mary Kathleen Group rocks east and west of the anticlinal Wonga belt.

Studies of the Corella Formation type section north of Mary Kathleen and east of the Wonga belt showed that metasediments there were similar to those in the Rosebud Syncline; i.e., laminated calc-silicate granofels of various types, para-amphibolite, calcareous quartzite, marble, and schist. In addition, the eastern areas of Corella Formation contain more metabasalt than the western areas, some acid metavolcanics, and locally foliated lenses of quartz-feldspar porphyry which may be either extrusive or intrusive. Further comments on the Corella Formation type section are presented by Blake in the Duchess Project report (this volume).

Facing criteria, stratigraphic continuity, lithological similarity and structural consistency confirm that the Corella Formation east and west of the Wonga belt are parts of the same sequence, probably deposited between 1780 and 1740 m.y. (Page, 1978, 1979)**.

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* BMR Journal of Australian Geology & Geophysics, 5, 243-56.

**Journal of the Geological Society of Australia, 25, 141-64, and BMR Report 212, 181-2, respectively.

Structure. Two areas of Corella Formation in the Rosebud Syncline were studied to determine the sequence of structural events. Original laminated to thin-bedded calcareous sedimentary layers (S_0) are cut at low angles by a southeast-trending cleavage or jointing (S_1), whose attitude is consistent with the outcrop location on the east limb of the Rosebud syncline. Some S_0 contacts and layers are displaced or rotated slightly by S_1, which is better developed in some S_0 layers than in others.

Further deformation resulted in some metamorphic differentiation in layers (S_2) grossly parallel to S_0. These S_2 layers appear to be zones of shear movement which resulted in drag-folding of the S_1 fracture-cleavage. The presence of both Z and S-type vergence in folded S_1 layers indicates possible isoclinal parasitic folding on the east limb of the regional syncline.

The formation of S_2 bands and the folding of S_1 were accompanied by the formation of secondary coarse-grained calcite (marble) in fold hinges of S_1, and in S_2. The calcitic S_2 layers contain fragments of adjacent S_0 lithologies. Calcite has also formed in local tension gashes which cut across S_0, S_1, and S_2.

Although at least two planar structural elements are recognised, it is not known whether they formed in separate deformational episodes, or in one relatively continuous and progressive deformation.

Tommy Creek area

Sills of Tommy Creek Microgranite intrude calc-silicate rocks mapped as Corella Formation in the central northern part of MARRABA. A U-Pb zircon date of about 1610 m.y. for the microgranite (Page, this report) places an upper limit on the age of the Corella Formation in this area. However, more specifically, the age of the Corella Formation throughout MARRABA may be younger than 1780 to 1760 m.y. (Argylla Formation age), and older than 1740 m.y. (age of Burstall Granite; Page, 1979).

Rhyolite from the same general area was also dated at about 1610 m.y. (Page, this report). It comes from a sequence mapped as a schistose and volcanic phase of the Corella Formation (Ekc_{2t}). This age thus appears to be anomalously young compared with the age of the Corella Formation noted above. One possible explanation is that the sequence interbedded with the dated rhyolite is not Corella Formation. A traverse through the dated sequence showed it contains abundant laminated black shale to slate, ortho-amphibolite, pyritic quartzite, rhyolite, phyllite, andalusite schist, garnetiferous metadacite or andesite, and garnetiferous basic to intermediate agglomerate. Calcareous or calc-silicate rocks are rare or absent.

No unconformities between this sequence and calc-silicate rocks have been observed. One interpretation is that the shale-volcanic sequence described above occurs in a small structural basin resting concordantly (and, as indicated by dating, disconformably) above the Corella Formation, and may warrant a separate name.

The new ages indicate that some deposition, metamorphism, and folding took place in the Eastern Succession long after deposition of the Mount Isa Group and equivalents in the Western Succession, which is at present thought to be the youngest sequence in the Mount Isa Inlier (Derrick, Wilson, & Sweet, 1980; Page, in press)*.

Lawn Hill Circular Structure by G.M. Derrick, I.H. Wilson & L.J. Hutton, (GSQ)

This feature is located immediately southeast of Lawn Hill homestead, in LAWN HILL. It is 18 km diameter. It comprises an inner ring 7 to 8 km diameter containing poorly exposed fine-grained tuffs and cherty siltstone of the Proterozoic Lawn Hill Formation, surrounded by an annulus of Border Waterhole Formation and Thorntonia Limestone - both Cambrian units. The Border Waterhole Formation is near-vertical in places, and possibly locally overturned; the Thorntonia Limestone is complexly and tectonically folded and faulted, and is cut by veins and dykes of limestone breccia. Both units are flat-lying and undeformed outside the circular structure.

Folded Lawn Hill Formation reappears outside the structure, and, although jointed, appears to be less brecciated than the same or similar units in the core of the structure. This core zone brecciation is mainly brittle fracturing and striation with slickensiding. The presence of shatter cones has not been definitely confirmed, and preliminary X-ray diffraction work failed to locate any high-pressure silica phases. The striations are vaguely radiating on curved fractures, and the apex of clustered striations plunged 40° to 220°, and 20° to 65° in the northwest, and 40° to 285° and 10° to 40° in the northwestern part of the central core.

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*BMR Journal of Australian Geology & Geophysics, 5, 215-23, and Economic Geology, respectively.

Breccias of the Thorntonia Limestone form veins and dykes from 0.5 to 20 m thick and contain fragments of micritic limestone; calcareous siltstone; chert; pelletal, oolitic, and fossilferous limestone; and some dolomite - all in a finely crystalline carbonate matrix. Blocks of bedded limestone up to 100 m long also occur in some breccia. Chert nodules in the breccia are generally similar to those in the bedded limestones, which indicate that brecciation post-dates the early diagenetic formation of the chert nodules. Fossils in the Thorntonia Limestone include Hyolithes, Girvanella, Biconulites (in coquinites), and trilobite fragments. Brecciation of the Thorntonia Limestone is uncommon in major exposures of the formation elsewhere, and no relatively thick evaporite-bearing sequences sufficient to cause solution collapse breccia have been recorded.

Origin. Any theory of origin for the structure must consider the following observations:-

1. The large and generally circular shape is unique to this area.
2. Units in the structure are arranged in apparently normal stratigraphic order.
3. Cambrian rocks are flat-lying outside of the structure, but show local steep dips within it, especially the basal Border Waterhole Formation.
4. The Thorntonia Limestone shows extensive brecciation and folding; dykes of breccia are both cross-cutting and parallel to bedding, and post-date the diagenetic formation of chert nodules.
5. Brecciated Lawn Hill Formation occurs in the core of the structure, and folded and possibly less brecciated Lawn Hill Formation occurs outside it.

Possible origins include:

A: Debris flow in a Cambrian basin. Cambrian strata were deposited unconformably on Lawn Hill Formation; earthquakes or gravitational collapse resulted in debris-flow breccias forming on a fore-reef slope or collapsed platform margin. The distribution of breccia requires that the original sedimentary basin was circular or restricted, and that debris flow was directed towards the centre of the basin, which is contrary to normal circumstances in which debris flow deposits are tongue-like and unidirectional down the fore-reef slope. No significant reefs have been observed elsewhere in the Thorntonia Limestone.

Observations 1, 3, and 5 are not adequately explained by this theory.

B: Meteorite impact. Impact events readily form circular structures; commonly the depression is filled with breccia derived from country rock, and commonly there is much overturning and uplift of central parts of the crater after impact. None of these features have been observed, although there are large areas of little or no outcrop in the central part of the structure, and facing of the Lawn Hill Formation in the core has not been determined. Certainly the core rocks are brecciated to a degree, but bedding appears to be relatively continuous. The limestone breccias also cannot be a result of direct impact, since the limestone country rock between the breccia dykes appears to be little altered or brecciated. This origin satisfies observations 1 and 5, but is not entirely compatible for 2; observations 3 and 4 may be consistent with the impact theory.

C: Igneous intrusion. This theory supposes some plug-like intrusion at depth may intrude with sufficient energy release to cause a massive explosion sufficient to form shatter cones and brecciation; additionally the country rock is uplifted or brecciated in advance of the intrusion. It is feasible that Lawn Hill Formation has been brecciated or fractured by such a mechanism, and the overlying Cambrian limestones domed upwards, causing folding; relaxation of stress may have caused further folding and dyke-like intrusion of breccias.

Most observations 1 to 5 satisfy this theory to some degree, but no igneous rock has been found in the area, and no igneous rocks of post-Cambrian age are known in the general area.

OFFICE ACTIVITIES

Maps

First Edition 1:100 000: SEIGAL, HEDLEYS CREEK, PROSPECTOR, KENNEDY GAP, and QUAMBY were published; LAWN HILL REGION is with the editors, and ALSACE is in preparation.

Preliminary Edition 1:100 000: MYALLY is with the printers; CARRARA RANGE REGION, CONSTANCE RANGE REGION, and COLULLAH are at an advanced stage, and MOUNT OXIDE is awaiting marginal detail.

Field compilation: MAMMOTH MINES is complete; generalisation of published maps for presentation at 1:250 000 has commenced.

Reporting of results

Records were issued for MARRABA geochemistry (1979/85), QUAMBY (1979/56), and KENNEDY GAP (1979/24); LAWN HILL/RIVERSLEIGH REGION(1980/43) is with the printer; ALSACE and CARRARA RANGE REGION are in preparation. GSQ Record 1979/44 describes the joint BMR/GSQ field studies of 1979.

Map Commentaries were published for MARRABA, and are in preparation for SEIGAL-HEDLEYS CREEK and LAWN HILL REGION. Manuscripts on stratigraphic nomenclature and chemical analyses of rocks in SEIGAL and HEDLEYS CREEK (BMR Reports 225 and 226 respectively) are with the editors. Papers were published in the Queensland Government Mining Journal by Wilson on company activity in the Dobbyn 1:250 000 Sheet area; by Wilson & others on the Kajabbi Formation, a new Cambrian unit near Kajabbi; and by Hutton & Sweet defining the Kamarga Volcanics in LAWN HILL.

A paper on the Quilalar and Surprise Creek Formations, by Derrick, Wilson, & Sweet was published in the BMR Journal, volume 5, and a paper by Derrick & Wilson discussing aspects of a paper by R.J. Holcombe on Wonga belt rocks was submitted to the Geological Society of Australia. Derrick co-authored a paper on Mary Kathleen uranium published in the IAEA volume on Uranium in the Pine Creek Geosyncline; the paper by Plumb, Derrick, & Wilson on the Precambrian of the McArthur-Mount Isa region was published; Wilson contributed further to Notes accompanying the Geological Map of Queensland.

Lectures were presented by Derrick to BMR on gneissic rocks at Mount Isa, and the anatomy of a Proterozoic rift zone at Mount Isa; the latter talk was also presented at the International Geological Congress in Paris in July (see below).

Other reports in preparation describe stratigraphic drilling in LAWN HILL (Hutton & Sweet) and definition of units in the McNamara Group (Hutton, Cavaney, & Sweet).

Miscellaneous

Derrick and Wilson attended the International Geological Congress in Paris. Derrick's paper stressed the evolution of a major rift structure in the Proterozoic of the Mount Isa region, and delineated a major subsidiary horst block within the rift (the Mount Gordon Arch). A significant result of this study was the documentation of a major period of growth-faulting which took place along the flanks of the Mount Gordon Arch during lower Mount Isa Group time, immediately preceding ore deposition at Mount Isa. Wilson discussed the volcanics of the Mount Isa Inlier and their geochemical variation through time. Both these lectures are being prepared as papers for publication; abstracts have been published in volume II of IGC abstracts.

Derrick also visited the Geological Survey of Canada and discussed aspects of mineral deposit geology and Precambrian geology; discussions were held with Dr T. Krogh in Toronto regarding the latest techniques in U-Pb zircon geochronology (see report on International Conferences and Overseas Visits).

Derrick prepared explanatory notes for the Solid Geology map of the Earth Science Atlas series; assisted I. Hone with preparation for geophysical studies of the Mount Isa Inlier; contributed to a review of the Metalliferous Section; made initial preparations for a symposium on Mount Isa geology in Mount Isa in September 1981; and continued discussion with D.H. Blake and R. Bultitude on aspects of nomenclature and correlation between the Duchess and Cloncurry areas.

Sweet departed from BMR in September 1980 on 12-months study leave to Reading University. He will undertake a course in advanced sedimentology offered by Dr J.R.L. Allen.

Sweet and Derrick attended the 'Geological environments and structural controls of ore deposits' course presented by T. Hopwood at BMR during November 1979.

DUCHESS PROJECT

by

D.H. Blake, R.J. Bultitude, & P.J.T. Donchak

STAFF: D.H. Blake (Project Leader); R.J. Bultitude; A.L. Jaques (part time); P.J.T. Donchak (GSQ); G.A. Young (draftswoman, part time).

AIMS: to review, by field and laboratory research, the stratigraphy, structure, geological history, and mineral potential of the Precambrian parts of the Duchess and Urandangi 1:250 000 Sheet areas, and to relate the Precambrian rocks to those previously mapped by G.M. Derrick and co-workers in the adjoining Cloncurry and Mount Isa 1:250 000 Sheet areas to the north.

The project is scheduled for completion by mid-1981.

FIELD ACTIVITIES

Limited field research was carried out in August and September in MALBON and adjoining 1:100 000 Sheet areas. Units mapped in MALBON were matched with those in the other sheet areas. In MARRABA examinations were made of the type section area of the Corella Formation and the Tommy Creek Microgranite and the Burstall Granite/Lunch Creek Gabbro areas. In MARY KATHLEEN the Corella Formation reference section along the Barkly Highway, the Rosebud Syncline area, and the Pelican Waterhole exposures of Mount Philp Breccia were examined. In DUCHESS, field investigations were concentrated on gneissic and schistose felsic rocks in the west, relations between the Argylla Formation and the Corella Formation to the east, and the Pilgrim Fault Zone.

The following conclusions were drawn from the field investigations.

1. The Precambrian stratigraphic units in the east of MALBON are tightly to isoclinally folded; hence the previously postulated eastward-younging sequence from the Argylla Formation in the west to the Kuridala Formation in the east is an oversimplification, and the Kuridala Formation may not be the youngest unit in the succession.

2. The Kuridala Formation in the Kuridala area (MALBON and MOUNT ANGELAY) has been folded into two major second-generation synforms. The western one, known as the Hampden Syncline, is outlined by dolerite sills. The eastern synform has been deformed by both east-west and vertical stresses, resulting in the development of a third-generation open synform, plunging gently to the south-southeast which locally has open parasitic folds on its limbs.

3. The Mitakoodi Quartzite in MALBON and DUCHESS includes some felsic volcanics similar to those of the underlying Argylla Formation.

4. The Mick Creek Sandstone in northwestern MOUNT ANGELAY and southwestern CLONCURRY may be part of a nappe: it forms a gently plunging antiform, surrounded by chaotic breccia, but the beds are overturned, hence the antiform is an inverted syncline.

5. The Corella Formation in its type section area in MARRABA contains a wide variety of tightly to isoclinally folded calcareous and non-calcareous metasediments and mafic metavolcanics, and is cut by several major faults. It shows no clear internal or external stratigraphic relations. Most of the rocks are not closely comparable to those of the Corella Formation either in the reference section or in the Rosebud Syncline area in MARY KATHLEEN.

6. A sequence of variably ferruginous, feldspathic, siliceous, and calcarous low-grade metasediments previously mapped as Corella Formation (most of unit Ekc_3 in MALBON, unit Ekc_x in MOUNT ANGELAY, and part of unit Ekc in CLONCURRY) and as Staveley Formation (in SELWYN REGION) are probably correlatives of the Marimo Slate sequence in southeast MARRABA and northeast MALBON. Breccia underlying this sequence in MARRABA and MALBON and mapped as Chumvale Breccia and Overhang Jaspilite may be a fossil regolith marking a major low-angle unconformity, as suggested by some previous workers.

7. Rocks previously mapped as Corella Formation east of the Pilgrim Fault Zone in DUCHESS probably belong to the Overhang Jaspilite.

8. In DUCHESS the main outcrop of Argylla Formation is separated from the broad belt of Corella Formation to the east by mafic metavolcanics assigned to the Magna Lynn Metabasalt, but between the mafic rocks and the Corella Formation a thin felsic metavolcanic unit, mapped as Argylla Formation, is generally present. All units have concordant contacts, but the order of superposition is uncertain because no structures indicating facing were found.

9. In the Corella Formation some 20 km north of Duchess township, open to tight second-generation (F_2) folding has refolded tight to isoclinal first-generation (F_1) folds. Recrystallisation and minor metamorphic differentiation took place during both fold events, indicating two periods of regional metamorphism. Thin dolerite dykes were intruded during the F_1 folding event. Major folds in a north-south zone to the east are considered to be F_2 folds.

10. The Mount Philp Breccia at Pelican Waterhole, MARY KATHLEEN, contains blocks of pegmatite, foliated metabasalt, and banded calc-silicate rocks, and must have been formed some time after the adjacent Corella Formation had been folded and metamorphosed.

11. Contact relations between the Lunch Creek Gabbro and Burstall Granite examined in MARRABA are of the net-veined complex type, and indicate that the gabbro was probably intruded into the granite, not vice versa as suggested previously.
12. Extensively recrystallised interlayered felsic and mafic metavolcanics and conglomeratic metasediments in southwest DUCHESS, previously mapped as part of the undivided Tewinga Group, are virtually identical to rocks mapped as Bottletree Formation along strike to the north.
13. In DUCHESS, rocks previously mapped as Leichhardt Metamorphics include a belt of highly sheared felsic porphyries, to be mapped as Leichhardt Volcanics, which lies to the east of belts of rhyolitic to dacitic gneissic metavolcanics, extensively intruded by granite, to be mapped as undivided Tewinga Group.

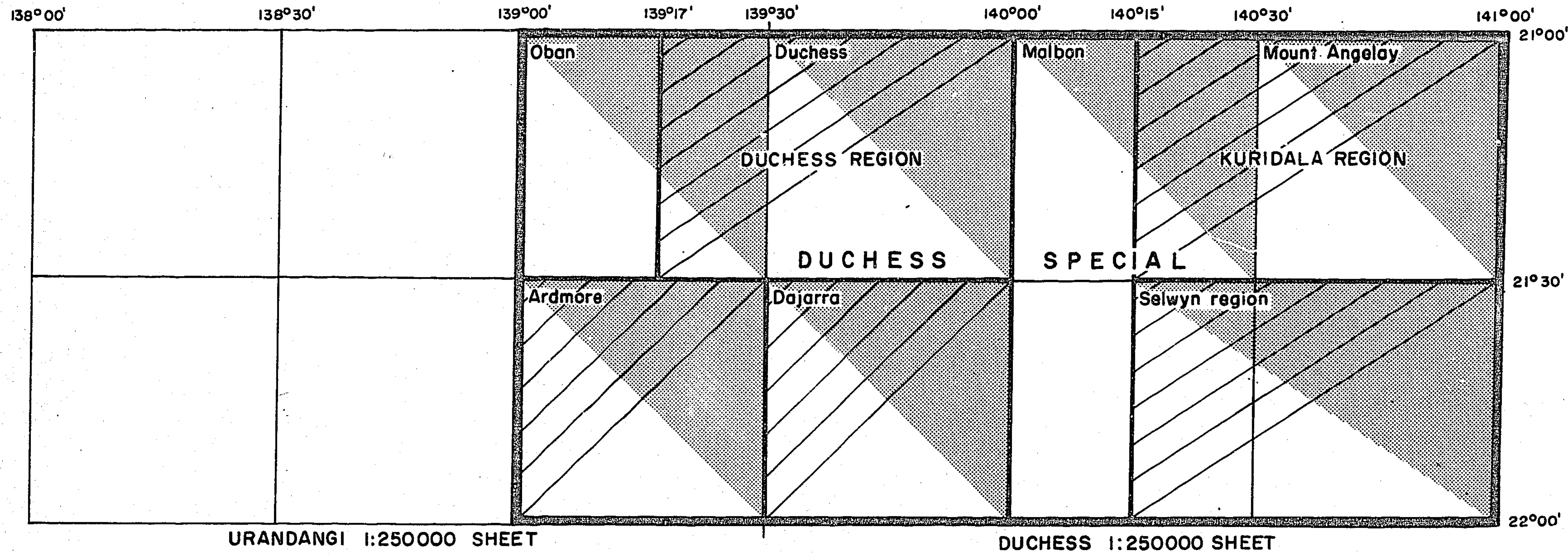
OTHER ACTIVITIES

Preparation of reports and maps

Reports on the Precambrian geology of SELWYN REGION, MOUNT ANGELAY, and ARDMORE, accompanied by 1:100 000-scale Preliminary Edition maps, were completed and issued as BMR Records 1979/86, 1979/93, and 1980/16 respectively; a report on the geology of OBAN was also issued (BMR Record 1978/87). All 1:100 000-scale Preliminary Edition maps and geological reports for the Precambrian parts of the Duchess and Urandangi 1:250 000 Sheet areas have now been released.

A paper by D.H. Blake, entitled 'The early geological history of the Proterozoic Mount Isa Inlier, northwestern Queensland: an alternative interpretation', is in press (BMR Journal). In this paper it is suggested that most of the Haslingden Group is older than the Argylla Formation and that part of the Corella Formation antedates the Haslingden Group.

Several maps, reports, and papers are in various stages of preparation. These include the following 1st Edition maps (Fig. M8) and accompanying Commentaries: DUCHESS REGION (special), DAJARRA, and SELWYN REGION (special), which are with the map editors, and KURIDALA REGION (special) and ARDMORE, which are expected to reach the map editors before 1981. Also being prepared is the Duchess Special 1:250 000 Sheet, which will be accompanied by a summary report on the geology and mineral potential of the area; a report on definitions of newly named and revised Precambrian stratigraphic and intrusive rock units; and papers on the Mount Philp Breccia and on intrusive net-veined complexes.



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F54/A/81

1:100000 Preliminary edition (issued)

1:100000 Coloured first edition (in preparation)

1:250000 Coloured special (in preparation)

Fig. M8 Duchess project maps.

Stratigraphic nomenclature

With the project nearing completion, and maps and reports being finalised for publication, it has become clear that some revision to the previous stratigraphic nomenclature is necessary. Several changes in nomenclature have been proposed and most of these have been approved. They include new names for many of the discrete mappable granite bodies; naming as the Yappo Formation a sequence of conglomerates and greywackes which correlates with the lower Mount Guide Quartzite mapped in MARY KATHLEEN; and naming as the Bottletree Formation a sequence of similar rocks, interbedded with mafic and felsic volcanics, underlying the Yappo Formation and mapped as Argylla Formation in MARY KATHLEEN.

Little metamorphosed porphyritic felsic volcanics in DAJARRA and southern DUCHESS, provisionally named the Standish volcanics, are now known to be similar in age, as well as in lithology and chemistry, to rocks mapped as Leichhardt Metamorphics to the north; because they are clearly volcanic rocks, rather than metamorphic rocks, they will be named Leichhardt Volcanics.

Rocks previously mapped as Corella Formation in MOUNT ANGELAY, MALBON, and SELWYN REGION will be assigned to two formations. One of these consists mainly of banded and brecciated amphibolite-grade calc-silicate rocks, but also includes metarhyolite isotopically dated at about 1700 m.y. The other formation, which crops out to the west, consists of lower-grade, partly calcareous sedimentary rocks which are correlated with the Marimo Slate sequence in southeast MARRABA.

Geochronology, geochemistry, and metamorphic petrology (see Laboratory reports for further details)

Isotopic age determinations by R.W. Page using the U-Pb zircon technique, have provided dates for three units in the Duchess 1:250 000 Sheet area. Dacitic lavas from the Bottletree Formation are about 1800 m.y. old, quartz-feldspar porphyries of the Leichhardt Volcanics were erupted about 1885 m.y. ago, and metarhyolite from the 'Corella Formation' east of Selwyn was probably emplaced about 1700 m.y. ago.

Geochemical work on volcanics and granitic rocks from the Duchess/ Urandangi area has been undertaken by L.A.I. Wyborn. Preliminary results show that the granites were probably derived by partial melting of deep crustal igneous material; also, the Leichhardt Volcanics are comagmatic with Kalkadoon

Granite; felsic volcanics of the Argylla Formation are comagmatic with Bowlers Hole Granite; felsic metavolcanics in the Corella Formation in DUCHESS are comagmatic with Bushy Park Gneiss; and metarhyolite in 'Corella Formation' in SELWYN REGION is comagmatic with granite previously mapped as Williams Granite.

A study of the regional metamorphism in the eastern part of the Duchess 1:250 000 Sheet area by A.L. Jaques shows that three metamorphic zones can be recognised here: greenschist facies, lower to middle amphibolite facies, and middle to upper amphibolite facies. The metamorphism is of low-pressure type.

Courses and symposia

Blake and Bultitude attended a course on 'Geological environments and structural controls of ore deposits' given by Dr T. Hopwood at BMR from 7-14 November 1979. Blake also attended the GSA Symposium on the Gawler Craton, 11 December 1979, and the AMF course 'Geophysics for geologists 11-15 February 1980, both in Adelaide.

GEORGETOWN PROJECT

by

B.S. Oversby, D.E. Mackenzie, & I.W. Withnall

STAFF: Involved part to full-time in the project during 1980 were - W. Anfillof[3], K.J. Armstrong[2,6], J.H.C. Bain[1] (co-ordinator until October), L.P. Black[4], G.J. Butterworth[5], D.J. Gregg[6], G.A.M. Henderson[1], C.P. Knight[5], D.E. Mackenzie[1], C.R. Madden[2], P. P.Moffat[5], B.S. Oversby[1], J.G. Pyke[2], P.A. Scott[2], J.V. Warnick[1] (Geological Survey of Queensland), and I.W. Withnall[1] Geological Survey of Queensland.
([1] geology, [2] geochemistry, [3] geophysics, [4] geochronology, [5] drafting, [6] field camp management)

AIMS: The Georgetown Project aims to substantially enhance and integrate geological, geochemical, and geophysical knowledge of Proterozoic to Palaeozoic rocks in the Georgetown region, northeastern Queensland, as an aid to the discovery of unknown mineral deposits, and as a step towards eventual clarification of northeastern Australia's evolution.

PROGRESS

Field research in the central and western parts of the Georgetown region (mainly in GEORGETOWN, FORSAYTH, GILBERTON, FOREST HOME, NORTH HEAD, GILBERT RIVER, ESMERALDA, and CROYDON), and data collection on a roughly 1:25 000-scale basis using colour air photographs, are now essentially finished. A synthesis of geological results from the first five areas is being prepared as a special 1:250 000-scale full-colour map, with accompanying text. In addition, the relevant limited colour 1:100 000-scale Preliminary Edition Geological Series maps are being revised, and preparation of a data Record on FOREST HOME and NORTH HEAD is at a fairly advanced stage.

Geological data collected in GILBERT RIVER, ESMERALDA, and CROYDON have been combined into first-stage compilations at field scale; these will form the basis of further 1:100 000-scale Preliminary Edition Geological Series maps, and an additional 1:250 000-scale synthesis. Geochemical data from GEORGETOWN and GILBERTON have been processed, and will be presented as 1:100 000 stream sediment geochemistry series maps, or similar, supported by a report. Eventually, stream-sediment geochemical data accumulated in the whole Georgetown region will be combined so that the most meaningful background and threshold values for the 25 elements under investigation can be ascertained. The new values will also be used in preparation of syntheses.

Geological field research in the southeastern Georgetown region (mainly in parts of LYNDHURST, EINASLEIGH, BURGES, and CONJUBOY continued during the year.

FIELD ACTIVITIES

Mackenzie, Henderson, and Warrick spent the period from early June to mid-September studying the geology of CROYDON, GILBERT RIVER, ESMERALDA, and parts of WALLABADAH, STRATHMORE, PROSPECT, and PELHAM, Bain also participated during June. Most attention was paid to Proterozoic to Palaeozoic rocks and their mineral deposits, but Mesozoic and Cainozoic rocks were also examined.

Scott, Dent, Armstrong, Madden, and Pyke spent various parts of the same period collecting and processing stream-sediment geochemical samples from the same areas, and also from FOREST HOME, NORTH HEAD, and GILBERTON. Sampling density was roughly 1 per 5 km^2 (see also Laboratory report).

Oversby and Withnall spent the period from early July to early October continuing a study of metamorphic and granitoid rocks. Although most attention was paid to Einasleigh and 'Balcooma' Metamorphics, adjacent units - as well as the Bagstowe and Lochaber centred igneous 'complexes' - were also examined.

CROYDON AND ADJACENT 1:100 000 SHEET AREAS (Fig. M9)

Croydon Volcanics

The Proterozoic Croydon Volcanics have been divided into seven main units of formation status. These are, in ascending stratigraphic order, 'Goat Creek Basalt', 'Pleasant Creek Andesite', 'Wonnemarra Rhyolite', 'B Creek Dacite', 'Parrot Camp Rhyolite', 'Carron Rhyolite', and 'Idalia Rhyolite' (names have been reserved with the Central Register of Australian Stratigraphic Names).

The 'Goat Creek Basalt' crops out discontinuously along the eastern and northwestern margins of the Croydon Volcanics 'block'; its thickness ranges from about 10 m to almost 100 m. It is a fine-grained aphanitic to slightly porphyritic, commonly amygdaloidal (agatiferous) basalt.

The 'Pleasant Creek Andesite' crops out along part of the eastern margin of the block; its thickness is uncertain, but possibly up to 200 m. It consists of porphyritic andesitic lava and agglomerate, crystal-poor andesitic tuff and ignimbrite, and minor intercalated basalt.

The 'Wonnemarra Rhyolite', a crystal-rich rhyolitic ignimbrite, occurs only on the southeastern margin of the block and is almost indistinguishable, apart from its stratigraphic position, from the 'Idalia Rhyolite' (below); it appears to be partly intrusive.

The 'B Creek Dacite' crops out extensively along the eastern and northern margins of the Croydon volcanic complex, and is about 15-250 m thick. It consists of moderately crystal-poor dacitic ignimbrite and moderately porphyritic dacitic lava and agglomerate.

The 'Parrot Camp Rhyolite' occurs only in the area northeast of Croydon. It is a crystal-rich rhyolitic ignimbrite similar to the 'Idalia' and 'Wonnemarra' Rhyolites, and is up to about 200 m thick.

The 'Carron Rhyolite' occurs extensively throughout the Croydon Volcanics except along the western margin; its thickness is about 200-300 m. It consists of crystal-poor, fine-grained rhyolitic ignimbrite with very fine eutaxitic foliation (which commonly shows fluidal deformation), and finely flow-banded to flow-laminated phenocryst-poor rhyolite; similar rhyolite occurs as dykes, mostly in the north of the region.

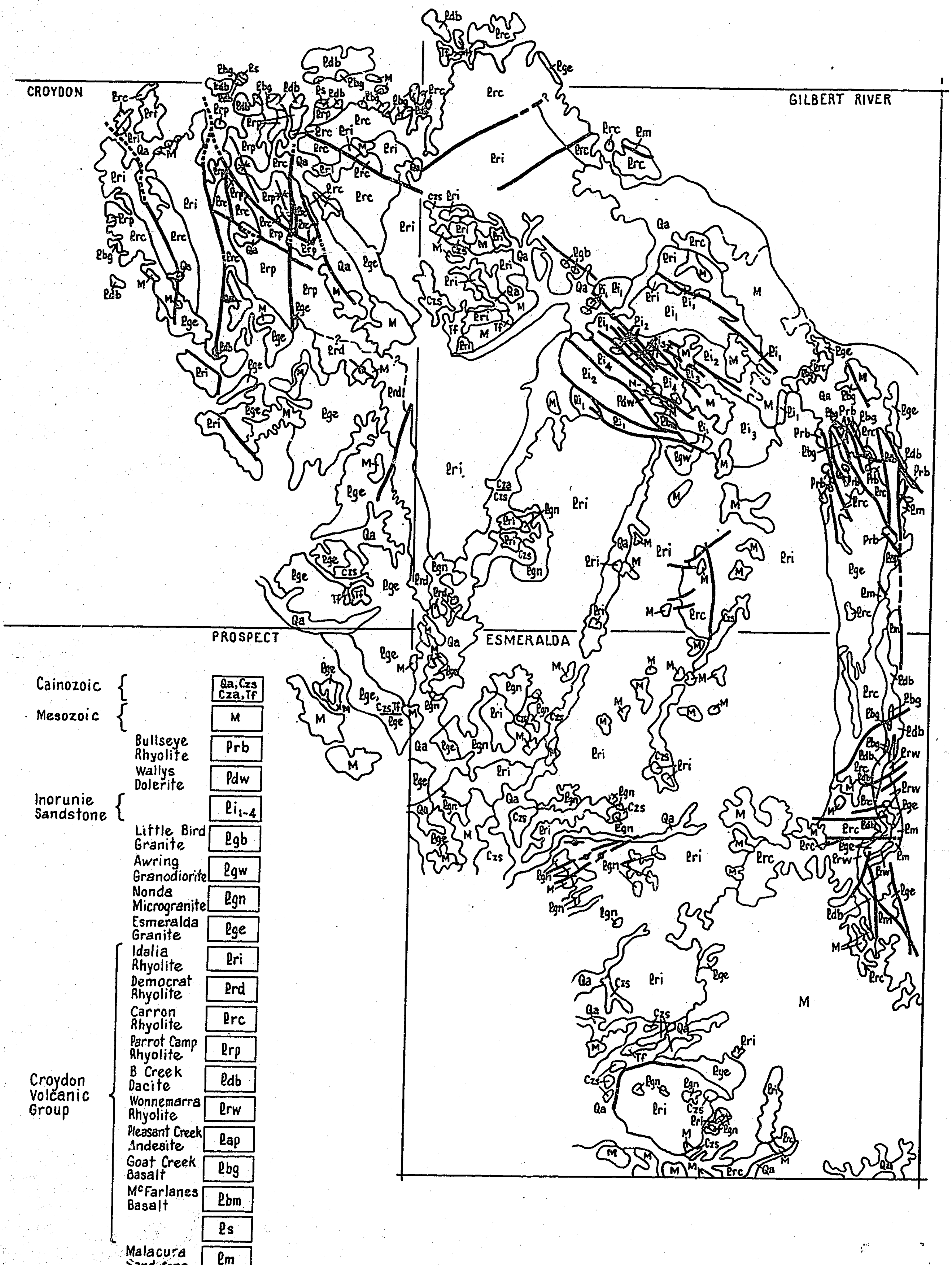

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Fig. M9 Generalised geology of the Croydon region, NE Queensland

The 'Idalia Rhyolite' is by far the most extensive unit, covering most of the Gregory Range area. It is a sequence up to 300 m thick made up of numerous flow units of massive, densely compacted, welded, and partly recrystallised crystal-rich rhyolitic ignimbrite. Despite the degree of welding and recrystallisation, however, spectacular eutaxitic textures are preserved in some places. The 'Idalia Rhyolite', in common with all the Croydon Volcanics, is rich in graphite and graphitic inclusions; in the rhyolite units, the graphite is particularly conspicuous as rounded pellets up to about 1 cm across.

Structure of the Croydon Volcanics is generally very simple: flat-lying or subhorizontal volcanic units cut by a system of dip-slip faults. Major fault zones trending north-northeasterly exist along the upper Esmeralda Creek-Three X Creek valley, along the Middle Creek-upper Little River valleys, and along the upper Knife Creek-upper Pleasant Creek valleys. Block-faulting movements have resulted in the exposure of an inlier of 'Carron Rhyolite' in the upper Little River-Dinner Camp Creek area. The eastern margin of the Croydon Volcanics is partly fault-bounded and partly unconformable, but is fundamentally fault-controlled.

The gold-bearing area northeast of Croydon is more complex, having been gently to moderately folded and intensely faulted, mainly block-faulted. This faulting has been a major influence in the localisation of quartz-reef gold deposits.

Permian volcanics

The 'Bullseye Rhyolite' occurs as a number of small subhorizontal outliers and gently-dipping fault slices in central-eastern GILBERT RIVER. It consists of rhyolitic crystal-rich tuff, agglomerate, tuffaceous sandstone, and minor ignimbrite overlying basal sediments ranging from extremely coarse boulder conglomerate (composed mainly of clasts of Inorunie Sandstone) to fine clayey quartz sandstone. Silicified wood from this unit has been tentatively identified as Araucarioxylon (N. Morris, personal communication).

In the McFarlanes Waterhole area (central GILBERT RIVER) there are three volcanic units of uncertain or unknown age. The 'McFarlanes Basalt' is an amygdaloidal (agatiferous) basalt similar to the 'Goat Creek Basalt' and probably also Proterozoic. The 'Little Pocket Dacite' is a dacitic lava-agglomerate unit quite different from 'B Creek Dacite'; the third unit is a rhyolitic crystallithic tuff (unnamed) similar to tuffs of the 'Bullseye Rhyolite'. These last two units may be Permian in age.

Intrusive rocks

The Esmeralda Granite, in the west of the region, is a large, essentially flat-roofed pluton made up of coarse to very coarse-grained biotite granite; it is comagmatic with the Croydon Volcanics. Finer-grained, commonly more mafic phases of the Esmeralda Granite are common near its margins. In southwestern GILBERT RIVER and westernmost ESMERALDA, a mafic, slightly porphyritic fine-grained granitic unit (Nonda Microgranite) forms irregular stocks and apophyses into the volcanic pile. Several plutons of coarse-grained to porphyritic granites broadly similar to the Esmeralda Granite occur along the eastern margin of the Croydon Volcanics; these plutons also have subhorizontal to gently domed roofs, and have wide contact aureoles.

The 'Awring Granodiorite' is a small stock of medium to fine-grained, commonly porphyritic biotite granodiorite which is partly altered and mineralised (disseminated and vein Cu) and which may be either Devonian or Permo-Carboniferous.

Small intrusions of dolerite and microdiorite/microgabbro occur in the McFarlanes Waterhole area, where they may intrude Inorunie Sandstone; in the area east of the Pandanus Creek pluton, where they appear to be part of the Croydon Volcanics sequence; and in an area east of Glenora, where dolerite underlies and possibly intrudes the Idalia Rhyolite. The ages of these rocks are uncertain; at least some may be Palaeozoic.

Inorunie Sandstone

The Inorunie Sandstone has been divided into four units. The lowermost is the 'Guela Sandstone', a massive fine to medium orthoquartzite with rare micaceous bands. This is overlain by the 'Venture Formation' which is made up of variably ferruginous micaceous lithic-quartz siltstone and sandstone, shale, and minor orthoquartzite. The third unit is the 'Nannygoat Sandstone', which consists of thick-bedded fine to medium orthoquartzite with thin, softer micaceous interbeds. The 'Chulcee Formation', the uppermost unit, is similar to the Venture Formation. The sequence is cut by numerous faults, mostly trending northwest, along which mainly vertical movements have taken place.

Mesozoic and Cainozoic rocks

Plateau or mesa-forming Jurassic-Cretaceous sedimentary rocks occur extensively throughtout the area, especially in the south: these are the Hampstead Sandstone, Loth Formation, Yappar and Coffin Hill Members (Gilbert River Formation) and Wallumbilla Formation. The Upper Cretaceous-Lower Tertiary Bulimba Formation is patchily preserved, mainly in the north, and there is extensive development of later Tertiary colluvial, valley-fill, piedmont and alluvial deposits, and nodular ferricrete, as well as Quaternary and Recent colluvial, alluvial, and piedmont deposits.

Mineral deposits

Quartz-reef gold deposits - associated either with altered Esmeralda Granite rich in graphitic rock inclusions, or with fractured and altered, commonly graphitic Carron, Parrot Camp, or Idalia Rhyolites - are extensively developed in the Croydon area and in the Tabletop area to the northeast. Gold may occupy quartz veins, fractures, and altered rock in the headwaters of the Carron River (northern GILBERT RIVER), and forms scattered minor occurrences along the western side of the Croydon Volcanics.

Tin occurs mainly in the Mount Cassiterite-Stanhills area southeast of Croydon where it was mined from quartz-veined greisen zones in the Esmeralda Granite or a fine-grained mafic variant. Numerous other greisen zones occur in the same area, both in the granite and in the adjacent volcanic rocks. Greisen zones are also extensively developed in volcanic rocks capping the Pandanus Creek pluton in the east.

LYNDHURST AND ADJACENT 1:100 000 SHEET AREAS

Einasleigh Metamorphics

In very general terms, three main subunits constitute the Einasleigh Metamorphics in LYNDHURST, southernmost EINASLEIGH, and westernmost CONJUBOY. The lowest (or highest, depending on the direction of 'younging', which is indeterminate) of these is characterised by biotite schist and gneiss with metabasite lenses; it appears to be laterally equivalent to, and locally overlain (or underlain) by a second subunit, which consists of leucocratic quartz-feldspar granofels and gneiss. Both these subunits pass upwards (or downwards) into one dominated by calc-silicate gneiss. This last subunit, which is by far the most extensively developed of the three, contains bodies rich in barite and base-metals in its lowermost (or uppermost) part.

The rocks have been metamorphosed to at least middle amphibolite grade, and have undergone several major deformations. If the compositional bands represent original stratification transposed during a first event, sporadically identifiable isoclines which deform them are second-generation structures. Inferred third-generation folds which deform the isoclines are tight, and have steep, roughly east-striking axial planes. They are overprinted by similarly upright but more open folds with northerly striking axial traces. A fifth deformation of at least local extent is probably represented by an east-striking zone of intense retrogression near the boundary between LYNDHURST and EINASLEIGH.

In western CONJUBOY and northwestern BURGES, the Einasleigh Metamorphics have been intensely mylonitised for 2km west of their faulted contact with 'Balcooma Metamorphics' (below). This 2km-wide belt is evidently the full extent of the Balcooma Mylonite Zone, previously thought to be considerably wider.

The Einasleigh and Juntala Metamorphics (the latter dominated by muscovite schist) are separated by the Werrington Fault in most of the western Lyndhurst Sheet area. However, in the extreme southwest, the two units appear to be in stratigraphic contact.

Large (several kilometres long) roof pendants of sporadically migmatitic muscovite and biotite schist and gneiss in Dido Granodiorite of east-central LYNDHURST have previously been assigned to the Einasleigh Metamorphics. However, they may lie east of a southward extension of the Balcooma Mylonite Zone hidden beneath Cainozoic basalt and other rocks along the Einasleigh river plain, and belong to a separate sequence.

'Balcooma Metamorphics'

The 'Balcooma Metamorphics' (Fig. M10) are a mainly eastward-dipping overturned sequence of schistose volcanic and sedimentary rocks of lower amphibolite grade in the western half of CONJUBOY. The sequence is overlain unconformably by undeformed Devonian arkosic sandstone and coralline limestone, probable Carboniferous ignimbrite and lava, and Cainozoic rocks. Volcanic rocks in the 'Balcooma Metamorphics' are mostly felsic crystal tuffs to lithic agglomerates, with possible ignimbrites locally; they occur with subordinate metasedimentary interbeds in three subunits separated by intervals in which

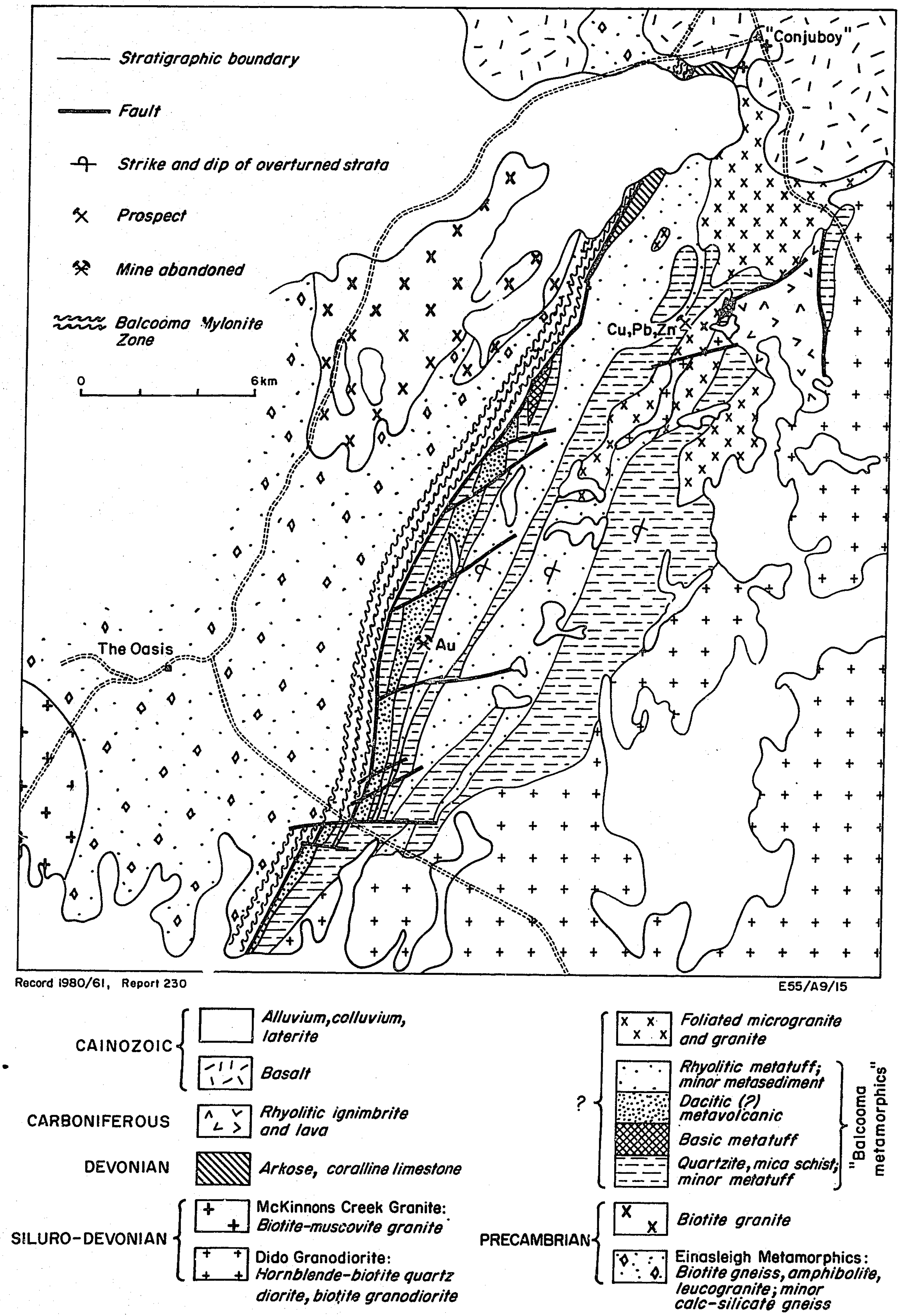

Fig. M10 Simplified geological map of the Balcooma area

metasediments predominate. These metasediments are fine to medium-grained biotite-muscovite schist and quartzite; coarse rocks are unknown. The overall thickness of the preserved sequence is about 4 000 m: however, individual subunits vary considerably along strike. Base-metal mineral deposits occur in metasedimentary rocks near the base of one of the volcanic-dominated subunits. The relative abundance of coarse volcanic rocks in the vicinity of these deposits suggests the proximity to a vent.

Preserved 'Balcooma Metamorphics' form the overturned limb of a major north-northeast to northeast-striking fold: this structure has been overprinted locally by an open, northeast-striking one. A possible third-generation fold is even more open, and strikes east.

Foliated biotite microgranite to granite bodies cut the lower part of the 'Balcooma Metamorphics': these rocks might be cogenetic with the volcanic ones. The whole assemblage has been intruded by the Dido Granodiorite.

The 'Balcooma Metamorphics' adjacent to the fault separating them from the Einasleigh Metamorphics (above) to the west are not markedly mylonitised, so that the timing of mylonite formation relative to deformations in the former unit is uncertain. The available evidence suggests that there might be a correlation with formation of the main northerly-striking overturned fold. Rocks assigned to the Dido Granodiorite and the slightly younger McKinnons Creek Granite, appear to have been emplaced during a late phase of the mylonitising event.

Bagstowe-Lochaber 'complexes'

Within the area of the Bagstowe ring-dyke structure, the pre-dyke Carboniferous Culba Granodiorite is apparently more extensive than originally thought. Older pre-dyke granitoids in the eastern part of the structure contain a well-developed north-striking foliation; this extends outside the ring-dyke system, becoming mylonitic towards the Warrington Fault. Farther to the northeast, the northern and eastern margins of the Lochaber Granite are rimmed by an older microgranite cut by shallow-dipping rhyolite sheets; rhyolite dykes occur farther away from the granite's edge. These bodies probably represent an early ring-dyke and cone-sheet, or bell-jar pluton, system, mostly dismembered and engulfed by the Lochaber Granite, rather than a chilled hood as previously postulated.

OFFICE ACTIVITIES

Georgetown 1:250 000 scale synthesis map

Bain, Oversby, Withnall, and Mackenzie spent most office time during the year in revising and rationalising information on relevant 1:100 000-scale Preliminary Edition Geological Series sheets (mainly GEORGETOWN, FORSAYTH, GILBERTON, FOREST HOME, and NORTH HEAD) for inclusion in the proposed full-colour Georgetown region synthesis map. Preparation of a key, and of rock relationship, structure, metamorphism, etc. diagrams, was also begun. Although the basic geological framework as presented previously will remain little-changed, the special map will incorporate many refinements relating to rock relations and distributions. In addition, the major region-wide deformation-metamorphism events will be distinguished by names - 'Ewamin' (D_1), 'Jana' (D_2), 'Tagalag' (D_3), and 'Warunu' (D_4) - derived from those of formerly indigenous Aboriginal groups.

Forest Home-North Head report

Withnall and Mackenzie commenced preparation of a report detailing the findings of field and laboratory studies of the Forest Home-North Head region. This work includes a major and trace-element rock geochemical study of the Proterozoic Candlow Formation (Etheridge Group), in which additional gold analyses and acquisition of other trace-element data have shown a strong positive correlation between Au and As, organic carbon and sulphur, and a negative correlation between Au and Zr. However, the highest Au values (20-90 ppb) are associated with pyrite, pyrite-rich carbonaceous rocks, and breccias, which are relatively minor components of the Candlow Formation. A petrographic study of the Candlow Formation has shown that chlorite is a common metamorphic mineral; reaction between chlorite and circulating groundwater containing sulphuric acid from the breakdown of pyrite has probably produced at least some of the hydrated Mg-sulphates that efflorescence previously attributed to dedolomitisation.

Geochemistry

Scott and Rossiter processed stream-sediment geochemical date from samples collected from GEORGETOWN and GILBERTON in 1978. Maps, and an accompanying report, arising from this work, are at an advanced stage of preparation.

Geochronology

Black processed several samples from various units in the Georgetown region, but no reliable ages were obtained.

Miscellaneous

Oversby presented a paper dealing with occurrences of volcanogenic sedimentary and 'pseudo-sedimentary' (partly of ignimbritic and ground surge origin) in the Newcastle Range Volcanics at the Fourth Australian Geological Convention, Hobart, in January. He also participated in the 'Lower Palaeozoic Geology of Western Tasmania' field symposium conducted by K.D. Corbett and A.V. Brown.

At the Ninth BMR Symposium in April, Mackenzie described the stratigraphy of the Etheridge Group as refined by recent work, fitted known mineral deposits into it, and predicted the possible occurrence of unknown deposits.

At the Australasian Institute of Mining and Metallurgy's New Zealand Conference in May, Bain discussed new ideas on the age and origin of Etheridge gold deposits, and implications for future exploration. He took part in an associated field symposium in the South Island.

Anfillof prepared a paper on the 1978 Agate Pocket detailed gravity survey for submission to the Bulletin of the Australian Society of Exploration Geophysicists.

VOLCANOLOGY

PAPUA NEW GUINEA VOLCANIC GEOLOGY, PETROLCGY, AND TECTONICS

by

R.W. Johnson

A wide range of activities was undertaken by the Volcanology Sub-Section this year. These included: preparation of a comprehensive volume of Papua New Guinea volcanological papers; collection and compilation of chemical data (obtained by X-ray fluorescence, electron microprobe analysis, spark-source mass spectrography, and mass spectrometry) on a wide range of Papua New Guinea volcanic-rock samples; publication of results of a petrological study on Boisa volcano; compilation of a bibliography of references to pre-1944 volcanic activity in Papua New Guinea; attendance and presentation of papers at three workshops and symposia.

COOKE-RAVIAN VOLUME OF VOLCANOLOGICAL PAPERS by R.J. Bultitude, V.F. Dent, I.B. Everingham, A.L. Jaques, R.W. Johnson, W.D. Palfreyman, & D.A. Wallace.

The major activity in volcanology this year was the preparation of a volume of volcanological papers to be published as a Geological Survey of Papua New Guinea Memoir. The volume is in honour of BMR geophysicist R.J.S. Cooke and his volcanological assistant E. Ravian who were killed by a phreatic eruption from Karkar volcano, Papua New Guinea, on 8 March 1979. Ravian was a volcano observer with the GSPNG Rabaul Volcanological Observatory. Cooke was Senior Government Volcanologist at Rabaul, and had been seconded there from BMR in 1971.

The volume contains 25 research papers on Papua New Guinea volcanoes, in addition to biographical articles on Cooke and Ravian, and was edited by R.W. Johnson. Nine of the papers have Cooke as sole or co-author. Nine papers were authored or co-authored by the seven BMR officers listed above; summaries of these are given in the following.

Literature search for pre-1945 sightings of volcanoes and their activity on Bougainville Island by R.J. Bultitude.

Records of volcanic activity on Bougainville before 1875 are very rare and represent an incomplete history of eruptive activity. A report of possible volcanic activity in northern Bougainville in 1796, and a sighting of Bagana volcano emitting a vapour plume from the summit area in 1842, are the only reports found of pre-1875 activity. Many of the numerous reports of activity between about 1875 and 1910 are conflicting and confusing, mainly because most of the sightings were made from ships, commonly at considerable distances from the volcanoes.

Note on activity from Bagana volcano from 1975 to 1980 by R. J. Bultitude & R.J.S. Cooke

The predominant activity at Bagana volcano between 1975 and 1980 was the almost continuous, but slow, extrusion of lava. Lava flow from the southern flank had continued intermittently since June 1966 until sometime between April and early June 1975, when a lava dome in the southeastern part of the summit crater was destroyed and ash-laden eruption clouds were produced. A new lava dome then began to grow in the northwestern part of the crater, and lava flow was redirected down the northwestern flank of the volcano. There has been almost continuous effusion of sluggish lava flows since June 1975 over much of the same path on the northwestern flank of the volcano.

Bam volcano: morphology, geology, and reported eruptive history by R.J.S. Cooke & R.W. Johnson

Bam Island is one of the least active of the 10 historically active volcanoes in the Bismarck volcanic arc. It is the andesitic top of a mainly submarine central-type volcano. Minor explosive eruptions from a deep summit crater were recorded between 1954 and 1960, but few observers report previous events that can unequivocally be identified as eruptions, although stories told by the islanders on Bam may refer to them. Lava flows are a main constituent of the island, but none has been produced in historial time.

Quaternary volcanism on Manus and M'Buke Islands by A.L. Jaques

Quaternary basalt is widely distributed around a caldera that forms Southwest Bay in southwestern Manus Island. The basalts are of transitional to mildly alkaline composition, rich in TiO_2, Zr, Nb, and light rare-earth elements, and resemble the incompatible-element-enriched tholeiites of oceanic islands such as Hawaii and Iceland. A change from island-arc (plate-boundary) igneous activity in the Tertiary to ocean-island type (intraplate) volcanism in the Quaternary, reflects a striking change in tectonic setting thought to have resulted from left-lateral translation of Manus Island and New Ireland past New Britain. The Quaternary intraplate volcanism of Southwest Bay, M'Buke, and Johnstone Islands, and the St Andrew Strait Islands, may be controlled by a northwest-trending fracture system, but alternatively may represent a 'hot-spot' trace.

Submarine volcanic eruptions in Papua New Guinea: 1878 activity of Vulcan (Rabaul) and other examples by R.W. Johnson, I.B. Everingham, & R.J.S. Cooke.

Eleven sites of known or possible submarine volcanic eruptions or thermal activity in Papua New Guinea have been identified, but activity at only seven of them is reasonably well documented. The 1878 activity of Vulcan and the 1953-1957 activity of Tuluman are unequivocal submarine eruptions. Ritter volcano collapsed in 1888 causing the largest recorded tsunami in Papua New Guinea, and it probably produced minor submarine explosive activity in 1972 and 1974. Submarine disturbances of possible volcanic origin took place in the Ninigo Group in 1930, near Karkar Island in 1944 and 1951, near Lolobau Island in 1970, and in the central Bismarck Sea in 1972. Disturbances have also been reported from near the islands of Narage (in the late nineteenth century) and Kadovar (1976), though they were almost certainly not caused by submarine eruptions. Seafloor spreading is thought to be taking place in the Bismarck Sea and Woodlark Basin, but only one of the eleven sites - that of the central-Bismarck Sea disturbances of 1972 - is related to it. Most of the remaining examples are at, or close to, volcanoes along the southern margin of the Bismarck Sea, and therefore close to regular traffic lanes and observation points on land.

Lava fields in the inner caldera of Karkar volcano by C.O. McKee & D.A. Wallace

An andesitic lava field covered most of the floor of the inner caldera of Karkar volcano before 1974, and had apparently been produced from several vents around the southern and eastern base of Bagiai, the active cone on the caldera floor. Six or seven lava 'terraces' may be recognised on aerial photographs, and the youngest one - which may have been produced in 1895 - had a minimum volume of about $25 \times 10^6 m^3$. Numerous eruptive centres opened up again on Bagiai in 1974-1975, and about $70 \times 10^6 m^3$ of andesitic lava were produced, mainly from effusive vents on the lower part of the cone.

The estimated maximum rate of lava effusion is about 60 $m^3 s^{-1}$, and about 75 percent of the caldera floor (excluding Bagiai) was covered by new lava flows. Tephras produced by the March 1979 explosive eruption of Bagiai now cover the greater part of the pre-1974 and 1974-1975 lava fields. The last few centuries of activity on Karkar seem to have been dominated by effusive activity, but this may represent only one part of a possible eruptive cycle. Other parts of this cycle are more explosive, judging by exposures in the caldera walls of Karkar, and some are certainly climactic and caldera-forming.

Fatal hydro-eruption of Karkar volcano in 1979: development of a maar-like crater by C.O. McKee, D.A. Wallace, R.A. Almond, & B. Talai.

A sequence of oblique explosions was directed south-southeastwards from a vent near the base of Bagiai cone in the inner caldera of Karkar on 8 March 1979. The main blast mantled part of the caldera floor with debris, stripped vegetation from the caldera wall, devastated an area of rainforest on the caldera rim, and there destroyed an observation camp occupied by volcanologists R.J.S. Cooke and E. Ravian. The explosions were the largest of a series of explosive eruptions between January and August 1979 that took place from a new crater on the floor of the inner caldera. The explosions are believed to have been of phreatic, or steam-blast explosion type, generated by the vaporisation of groundwater in contact with hot rocks. The new crater is strikingly similar to a maar. There is a good correlation between periods of rainfall and the times of the explosions. No fresh magma seems to have erupted but a widespread area of fumarolic activity and a smaller one of incandescence on the caldera floor in late 1978, and increased volcanic tremor reaching a climax in late October 1978, are taken as evidence that a body of magma rose to a shallow depth beneath the caldera. A new program of seismic, tilt, and gravity measurements began in April 1979 to detect any changes that may precede larger-scale explosive activity. However, changes measured during 1979 were small, although some uplift and tilting of the summit area was detected. Resistivity and self-potential electrical surveys provided evidence for the existence of a 100-200 m-deep aquifer believed to have been the focus of the hydro-explosions.

Langila volcano: summary of reported eruptive history, and eruption periodicity from 1961 to 1972 by W.D. Palfreyman, D.A. Wallace, & R.J.S. Cooke

Langila volcano consists of four coalescent cones on the eastern flank of an extinct volcano, Mount Talawe, in western New Britain. It was first recognised as an active volcano in 1878, but a complete chronology of major events dates only from 1929 - the time of the first permanent European settlement in the area. Langila came under regular volcanological surveillance about 1950, and has since been observed to be more-or-less continuously active. Continuous low-pressure emission of white vapour is overridden at irregular intervals by the periodic hydro-explosive ejection of grey-ash-laden vapour clouds. This activity at times builds up into Vulcanian-Strombolian eruptions that consist of frequent, regular, and copious black-ash-laden vapour ejections, the expulsion of red-hot tephra, and some lava flows. There is no correlation between explosive activity and rainfall for the period 1961-1972, but peaks in Vulcanian-Strombolian activity in June-August and December-February, are evidence that the semi-annual solar tide may influence the eruptive activity of Langila in a significant way.

Kadovar volcano and investigations of an outbreak of thermal activity in 1976

D.A. Wallace, R.J.S. Cooke, V.F. Dent, D.J. Norris, & R.W. Johnson.

In September 1976 a weak fumarolic area developed on Kadovar Island, a volcano that may have last erupted in 1700 A.D. Regular inspections of the new thermal area were made over two years; seismic and magnetic observations were carried out, gas samples were collected, and temperatures were measured. Thermal activity closely followed an increase in shallow regional seismicity beginning in February 1976, which included a swarm of earthquakes in June and an aftershock swarm in August. Thermal activity intensified slightly until early 1977 when the affected area covered about 15 000 m^2, but it had declined markedly by September 1978. All vegetation was killed in the main thermal zone. Changes in accumulated strain, induced by local regional seismicity, are thought to have activated a body of magma at unknown depth below the volcano, and a possible trend towards an eruption may have been halted after further tectonic earthquakes took place in January 1977.

CHEMICAL DATA ACQUISITION AND CATALOGUING

Tabar-to-Feni Islands by D.A. Wallace and R.W. Johnson

Major-element analyses, and trace-element analyses determined by X-ray fluorescence, have been compiled for 116 volcanic rocks from the Tabar, Lihir, Tanga, and Feni Islands, north and east of New Ireland. The compilations were done in conjunction with Dr B.W. Chappell (Department of Geology, Australian National University) who provided many of the analyses. Most of the rocks are alkaline; markedly undersaturated ones have conspicuous phenocrysts of the pleochroic feldspathoid, hauyne. Quartz trachytes are represented on some islands.

Dr R.J. Arculus (Research School of Earth Sciences, ANU) has completed an electron microprobe study of the mineralogy of a suite of 40 samples from the Tabar-to-Feni Islands, including some amphibole-bearing coarse-grained igneous inclusions found in many of the lavas. These microprobe results are to be tabulated with the whole-rock analyses, and with a set of new initial $^{87}Sr/^{86}Sr$ values for 16 samples, determined by Dr M.R. Perfit (also of RSES, ANU). All the analytical results will accompany systematic geological descriptions of each island which have been completed by D.A. Wallace.

Lolobau Island, New Britain by R.W. Johnson

Lolobau Island is a Quaternary volcanic complex in the New Britain island arc, and is made up of silica-oversaturated rocks ranging from tholeiitic basalt, through andesite and dacite, to rhyolite. All of these rock types are found in three stratigraphic groups. Dacite was produced by the last eruption at the turn of the century.

A suite of rocks from Lolobau Island has been analysed, and an electron-microprobe study has been undertaken by co-worker J.L. Banner (Department of Earth and Space Sciences, State University of New York at Stony Brook, USA). Interpretation of results is still at a preliminary stage, but low-pressure fractional crystallisation appears to be the most important process in producing the spectrum of compositions at Lolobau. However, mixing of magmas and incorporation of xenocrysts by rising magmas may also have played a significant part.

Sogeri Plateau, near Port Moresby by R.W. Johnson

An unusual sequence of Pliocene volcaniclastic rocks, the Astrolabe Agglomerate, makes up the Sogeri Plateau just east of Port Moresby. A suite of 29 mainly fresh rocks collected in 1979 from the interiors of larger clasts in the sequence has been chemically analysed by B.W. Chappell, and has been shown to consist mainly of arc-trench-type andesites containing more-or-less equal proportions of K_2O and Na_2O.

The rocks are similar in composition to the incompatible-element-enriched rocks from the Highlands Quaternary volcanic province and from other late Cainozoic volcanic areas in eastern Papua. Unlike these other areas the Sogeri rocks form a plateau, rather than central-type stratovolcanoes, but like them they highlight the tectonic problem of whether or not such magmas originate above a downgoing slab of oceanic lithosphere. There is no Benioff zone beneath the Sogeri Plateau at the present day.

Lamington volcano - the 1951 cumulodome by R.W. Johnson

Coarse-grained igneous inclusions and pieces of country rock are present in the hornblende-andesite cumulodome produced during the 1951 Pelean eruption of Mount Lamington. A collection of these inclusions and their host lavas was made in 1979. The lavas have been analysed by B.W. Chappell, and R.J. Arculus has completed detailed microprobe analysis of the mineralogy of the inclusions and related lavas.

The coarse-grained igneous inclusions consist mainly of amphibole, pyroxene, and plagioclase, and pieces of country rock include olivine and orthopyroxene from the harzburgite that makes up part of the Papuan Ultramafic Belt beneath Mount Lamington. Fragments of highly refractory minerals are also found dispersed in the 1951 lava.

AMPHIBOLE-BEARING INCLUSIONS FROM BOISA ISLAND, PAPUA NEW GUINEA: EVALUATION OF THE ROLE OF FRACTIONAL CRYSTALLISATION IN AN ANDESITIC VOLCANO by R.W. Johnson

Boisa Island is the tip of a Quaternary island-arc volcano off the north coast of New Guinea. It consists of an older cone made up of porphyritic, amphibole-free mafic rocks, and two younger cumulodomes of hornblende-bearing high-silica andesite. One of the cumulodomes contains coarse-grained igneous inclusions consisting of amphibole, plagioclase, clinopyroxene, orthopyroxene, olivine, and spinel. Some of these minerals in the andesites themselves have both cognate and xenocrystal components. A geochemical and petrological study has been made of these rocks in conjunction with Mr D.A. Gust (RSES, ANU), and results are discussed in a paper accepted for publication in Journal of Geology; the analytical data are tabulated in a BMR microfiche Report.

Both the anhydrous phenocryst assemblage in the Boisa basalts and the amphibole-bearing assemblage of the inclusions provide low residuals in least-squares linear-mixing calculations, suggesting that fractionation of either assemblage in the basalts could have given rise to the andesites. However, this is not supported by the results of Rayleigh-fractionation calculations for several incompatible elements. Four possible interpretations are: (1) the Rayleigh-fractionation results are inappropriate and misleading; (2) the andesites were formed by crystal fractionation of a mafic parental magma not represented on Boisa Island; (3) mixing of a fractionation parental magma with an incompatible-element depleted mafic magma (also not represented on Boisa); (4) mixing of mafic crystals represented by the Boisa inclusions with a magma richer in SiO_2 than the most felsic rocks on Boisa. This last interpretation is supported by petrographic evidence, but the origin and nature of the postulated felsic magma remain unclear.

BIBLIOGRAPHY OF REFERENCES TO PRE-1944 VOLCANIC ACTIVITY IN PAPUA NEW GUINEA, AND TRANSLATION OF GERMAN ARTICLES RELATING TO VOLCANOES AND VOLCANIC ACTIVITY DURING THE GERMAN COLONIAL PERIOD (1885-1914) by W.D. Palfreyman, R.W. Johnson, & R.J. Bultitude

A bibliography of more than 600 titles has been compiled of references to volcanoes and volcanic activity in Papua New Guinea before 1944. The bibliography has been built on the collection of references made by the late R.J.S. Cooke. Many of the references are in German, and relevant parts of them have been translated, mainly by Mrs S. Freymadl of Kokopo, New Britain. The bibliography will eventually be published as a BMR microfiche Report.

German staff of the Mission of the Sacred Heart in the Rabaul area of northeastern New Britain observed the explosive eruptions of Vulcan and Tavurvur volcanoes in late May and early June 1937. They also played a major role in setting up an evacuation camp at their mission headquarters in Vunapope for several thousand refugees from Rabaul and surrounding areas. Letters, accounts based on the letters, and additional articles by the missionaries were published in 1937 in the German mission journals Hiltruper Monatshefte and Liebfrauen Monatshefte. Translations of these reports have been made by Mrs A. Arculus (United Kingdom), and provide a substantial addition to the English-language record of the 1937 Rabaul eruptions. The translations have been compiled in a BMR microfiche Report.

SYMPOSIA AND WORKSHOPS by R.W. Johnson & D.A. Wallace

Johnson and Wallace attended the 17th General Assembly of the

International Union of Geodesy and Geophysics held in Canberra in December 1979. Johnson convened the International Commission on Geodynamics symposium 'Tectonics of the Southwest Pacific margin' at which 20 papers were presented on topics ranging from marine geophysics and regional geology to volcanic petrology and plate kinematics. Wallace presented a joint paper on the 1979 Karkar eruption at an International Association of Volcanology and Chemistry of the Earth's Interior workshop on mitigation of volcanic disasters. A resolution strongly recommending the setting up of a regional volcanological institute for the Western Pacific was passed unanimously at the final IAVCEI plenary session, and was subsequently accepted as an IUGG resolution. This proposal is at present being considered by UNESCO.

Johnson also attended the 3rd Southwest Pacific Workshop Symposium, held at the University of Sydney shortly after the IUGG Assembly, and presented a review paper on volcanology and tectonics in Papua New Guinea. He also attended the 2nd CCOP/SOPAC International Workshop 'Geology, mineral resources, and geophysics of the South Pacific' in Noumea (October, 1980), and gave two papers: one on magma genesis in New Britain; the other on volcanology in Australasia.

PETROLOGICAL, GEOCHEMICAL, AND GEOCHRONOLOGICAL LABORATORIES

Supervisor: A.D. Haldane

STAFF: L.P. Black, B.I. Cruikshank, V.F. Dent, G.R. Ewers, John Ferguson, A.L. Jaques, R.W. Page, P.A. Scott, J.W. Sheraton, L. Wyborn; technical staff: K.J. Armstrong, M.J. Bower, N.J. Davis, J. Duggan (to July), K.H. Ellingsen, J.L. Fitzsimmons, D. Guy (from February), N.C. Hyett, C.R. Madden (to July), J.G. Pyke, T.I. Slezak, T.K. Zapasnik.

PETROLOGICAL LABORATORY

PETROLOGY AND GEOCHEMISTRY OF IGNEOUS AND METAMORPHIC ROCKS FROM ANTARCTICA by J.W. Sheraton

Petrological and geochemical studies of igneous and metamorphic rocks from Enderby Land and MacRobertson Land, in conjunction with the geological mapping program have been completed. The basic petrographic data will be used in the compilation of 1:250 000 maps covering Enderby Land. Petrological and geochemical results have been or are being written up for publication.

Mafic igneous rocks by J.W. Sheraton, & L.P. Black

Isotopic dating has revealed a long history of mafic dyke emplacement in East Antarctica. The abundant Proterozoic dykes have tholeiitic affinities, whereas Phanerozoic intrusives and extrusives are mildly to intensely alkaline. In Enderby Land two distinct episodes of tholeiite dyke emplacement intersecting Archaean high-grade metamorphics of the Napier Complex have been identified. Lower Proterozoic (2350 $\pm$ 48 m.y.) tholeiites were intruded at considerable depths in the crust during the waning stages of granulite-facies metamorphism, and include a high-Mg suite with komatiitic affinites, ranging in composition from norite to mela-andesite. Middle Proterozoic Amundsen dykes are typical continental tholeiites, and most of the chemical variation in individual suites can be explained in terms of different degrees of partial melting and low-pressure crystal fractionation. Group I Amundsen tholeiites were derived from a homogeneous source region 1190 $\pm$ 200 m.y. ago, whereas the source of the group II tholeiites was chemically and isotopically heterogeneous. Group II dykes have various degrees of enrichment in incompatible elements, and commonly show normalised trace element abundance patterns with negative niobium anomalies. These features imply variable metasomatism of the source region by a volatile-rich fluid phase rather than a partial melt. This fluid phase was enriched, particularly in K, Rb, Ba, and, to a lesser extent, Th (and probably also Pb, U, and As in the high-Mg tholeiites). The available data suggest that the source regions of tholeiites from the Vestfold Hills and southern Prince Charles Mountains were generally less enriched than, but otherwise similar to, that of the group II tholeiites.

Lower Proterozoic tholeiites tend to have higher ratios of more-to-less incompatible elements (e.g., K/Zr, K/Ce) and larger niobium anomalies (i.e., higher K/Nb) compared with Middle Proterozoic tholeiites, suggesting derivation from more enriched source regions. However, isotopic data constrain source metasomatism to a time immediately before their emplacement, but are not compatible with significant crustal contamination.

<u>Felsic gneisses and granite intrusives</u> by J.W. Sheraton

Felsic orthopyroxene-quartz-feldspar gneisses which make up much of the Archaean Napier Complex of Enderby Land comprise two groups. The most abundant varies in composition from tonalite, through granodiorite, to (subordinate) granite, and is characterised by marked depletion in Y (and, by implication, heavy rare-earths). Compositionally similar gneisses are common in Archaean metamorphics of, for example, Greenland and northwest Scotland, and are considered to have been derived by partial melting of amphibolite or garnet amphibolite, possibly combined with hornblende fractionation. The second group, predominantly of trondhjemitic to granitic composition, does not show Y depletion, and is relatively rich in Ti, total Fe, Zr, and Nb, poor in Ca and Sr, and has high Ga/Al. These may have originated by remelting under relatively dry conditions of older tonalitic to granitic gneiss. Both groups show metamorphic depletion of Rb (relative to K), Th, and U.

Proterozoic intrusive rocks are mostly granite or granodiorite, and are commonly quite mafic and enriched in Fe. Some are unusually potassic, being similar in this respect to the Mawson Charnockite, and many are high in P_2O_5, Y, Zr, Nb, La, and Ce, reflecting the abundance of accessory phases such as apatite, zircon, and allanite. Th and U are commonly low, however.

Archaean gneisses of the southern Prince Charles Mountains do not appear to include analogues of the Y-poor tonalite-granodiorite-granite suite of Enderby Land, but abundant ferro-hastingsite-bearing gneisses and intrusives are similar in composition to the trondhjemite-granite suite and younger intrusives from Enderby Land; they are particularly enriched in Ti, total Fe, Y, Zr, Nb, La, and Ce. Such compositions are rare amongst Upper Proterozoic gneisses of the northern Prince Charles Mountains and Mawson coast. The relative heterogeneity of these and the abundance of garnet indicate a sedimentary origin for the majority.

The only possible indications of economic potential amongst the intrusive rocks are the relatively high Sn contents (up to 12 ppm) of Cambrian granites of the southern Prince Charles Mountains, and a very high value of 120 ppm Sn (and 1300 ppm Pb) in a single sample of granodiorite from Enderby Land.

DUCHESS METAMORPHICS by A.L. Jaques

A petrological study of the regionally metamorphosed Proterozoic rocks of the Selwyn Range area, northwest Queensland, has been carried out with the aim of determining the metamorphic history of the region and the P-T conditions of metamorphism.

Three metamorphic zones have been recognised. Zone A, the lowest grade, is characterised by the assemblage quartz-muscovite-biotite-(chlorite, graphite) in pelitic rocks, and quartz-albite-epidote-chlorite-actinolite-blue-green hornblende-sphene in mafic rocks.

In Zone B, of intermediate grade, pelitic rocks have been metamorphosed to porphyroblastic staurolite, almandine and/or andalusite-bearing mica schist, and calcareous rocks to granular calc-silicates typically with the assemblage albite-edenitic to pargasitic hornblende-sphene-(clinopyroxene, scapolite). Metabasites in this zone have been metamorphosed to foliated amphibolite with the assemblage oligoclase-green hornblende-ilmenite-(actinolite, clinopyroxene, quartz). In Zone C, the highest grade zone, pelitic rocks commonly contain sillimanite and/or almandine, and calcareous rocks commonly contain grossular-rich garnet, in addition to the Zone B assemblages. Zone C orthoamphibolites typically contain the assemblage plagioclase (commonly andesine-labradorite)-green-brown tschermakitic hornblende-clinopyroxene-almandine-ilmenite.

Comparison of the mineral assemblages with established isoreaction-grads and the application of geothermometers indicate that Zone A has been metamorphosed to conditions appropriate to the greenschist facies whereas Zones B and C have attained higher temperatures, corresponding to the lower to middle and middle to upper amphibolite facies respectively. The absence of kyanite, the presence of almandine and absence of cordierite on a regional scale, and other pressure-sensitive isoreaction-grads imply that metamorphism occurred at low pressure (~ 3-5 kb).

The metamorphic isograds parallel the regional trends and there appears to be a correlation between thermal axes and structure; i.e., the higher-grade rocks are exposed in anticlinal structures and the lower-grade rocks in synclinal features. Granitic bodies are either postmetamorphic or late synmetamorphic; some have narrow high-temperature contact aureoles. Features such as this are typical of greenschist-amphibolite terrains elsewhere in which emplacement of abundant granitic rocks occurs in a declining phase or at the end of regional metamorphism as a consequence of a high geothermal gradient.

OPHIOLITE AND BASALT PETROGENESIS by A.L. Jaques

Several papers dealing with the petrology and geochemistry of the ophiolite (peridotite-gabbro-basalt) complexes of Papua New Guinea have been prepared and others are in preparation. A paper on the ophiolites of Papua New Guinea was presented in the ICG Symposium at the IUGG in Canberra and at the Southwest Pacific Workshop Symposium in Sydney in December.

Marum ophiolite complex

A paper entitled 'Petrology and petrogenesis of cumulate peridotites and gabbros from the Marum ophiolite complex, northern Papua New Guinea' is to be published in a forthcoming issue of Journal of Petrology. A further paper on the non-cumulus peridotites is in preparation.

Papuan Ultramafic Belt

A paper on the Papuan Ultramafic Belt (co-author B.W. Chappell, Dept. Geology, Australian National University) has been accepted for publication in Contributions to Mineralogy and Petrology.

New petrological and geochemical data are presented for a suite of rocks from the Papuan Ultramafic Belt (PUB), Papua New Guinea. Tectonite peridotites at the base of the ophiolite have extremely refractory, uniform mineralogy and are exceptionally depleted in lithophile elements. These features are consistent with the proposed origin of these rocks as 'depleted' upper-mantle residual after extraction of a basaltic melt. The tectonite peridotites are overlain by a thick sequence of layered ultramafic and mafic cumulates containing olivine, orthopyroxene, clinopyroxene and plagioclase as the major cumulus phases. Early cumulates are characterised by highly magnesian olivine Mg_{90}, orthopyroxene Mg_{90} and calcic plagioclase An_{86}, and exhibit cryptic variation towards more iron-rich and sodic compositions. Abundances of 'incompatible' elements in the cumulates are extremely low, which together with the nature of the cumulus phases points to a magnesian olivine-poor tholeiite or magnesian quartz tholeiite parent magma(s) strongly depleted in 'incompatible' elements. Highly fractionated iron-rich products of this parent magma type are represented by the LREE-depleted lavas in the overlying basalt sequence which, although resembling the most depleted mid-ocean ridge basalts (MORB) in terms of their low abundances of 'incompatible' elements, have higher abundances of transition metals and lower abundances of Ti, HREE and other high valence cations compared with common MORB of similar Mg/(Mg + Fe) ratio.

Eocene tonalites intruding the PUB are genetically unrelated to the ophiolites, and appear to be related by crystal fractionation to the Ti-poor high-Mg andesites of Cape Vogel and similar andesites and dacites at the northern end of the PUB. These rocks are considered to represent the early stages of island-arc magmatism associated with a northeastward-dipping subduction zone in the early Eocene immediately before emplacement of the PUB.

Basalt genesis

A paper entitled 'Anhydrous melting of peridotite at 0-15 kb pressure and the genesis of tholeiitic basalts' (co-author D.H. Green) was presented at the IAVCEI symposium on 'Basaltic Volcanism on the Terrestrial Planets' at the IUGG in Canberra in December, and later published in Contributions to Mineralogy and Petrology.

PETROLOGICAL EXAMINATION OF SONNE CRUISE BASALTS by A.L. Jaques

A suite of seven rock sam[illegible]dged from the Wallaby Plateau area during the Sonne cruise was examine[illegible] The petrography and chemistry of the suite shows them to be intensely altered basaltic rocks. The least altered sample is an olivine tholeiite with trace-element characteristics resembling 'transitional tholeiites' or 'Group II' ocean floor basalts. The other samples appear to be more alkaline, although trace-element discrimination diagrams and ratios using those elements thought to be least affected by alteration processes do not uniquely categorise the volcanics. All the samples are, according to these plots, either of 'transitional' or tholeiitic affinity. Basalts of similar composition are found in 'anomalous' ridge segments, oceanic islands (e.g., Iceland), oceanic fracture zones, aseismic ridges, and seamounts. The geochemistry of the basalts is therefore more consistent with an oceanic rather than continental lithosphere.

ALKALINE ULTRAMAFIC ROCK PROJECT by John Ferguson

KIMBERLITES IN SOUTHEAST AUSTRALIA

Introduction

Although diamonds can occur in alluvial gravels and beach sands, their only primary source is kimberlite. About 88 percent of the world's diamond production comes from the primary source, so it is important to understand the tectonic controls of kimberlite emplacement. Any tectonic model proposed has to take cognisance of the empirical observation that diamondiferous kimberlites are confined to stable cratons that have not undergone orogenesis in the past 1500 m.y.

However, diamond is only an accessory mineral in kimberlites, occurring, if at all, in concentrations less than one part in a million, thus it is useful to have independent pressure (P) and temperature (T) estimates of depth of generation of kimberlites. By determining the site of generation of the kimberlite, it can be established whether formation took place in the diamond stability field, rather than at lower pressures, thereby endorsing the prospective nature of a kimberlitic province. Independent estimates of the site of generation of the kimberlites can be ascertained by:

a) comparing, with laboratory calibrations, P-T estimates derived from equilibrium mineral assemblages in mantle nodules (xenoliths) present in kimberlites;

b) comparing the composition of the magma with experimentally determined melting compositions on peridotitic rocks.

Tectonic setting

Kimberlites range in age from Precambrian to Cretaceous and possibly Tertiary. They are confined to continental settings in an anorogenic environment. Although kimberlite intrusives can be widely dispersed throughout continental terrains, the diamondiferous-bearing ones are confined to cratonic areas that have not undergone an orogenic event in the past 1500 m.y.

Field occurrences indicate that all fifteen kimberlitic intrusives in southeastern Australia postdate the Proterozoic. Isotopic dating of whole rocks and phlogopite indicate a spread of ages. However, ages derived from phlogopite analyses may not be the age of the intrusive event, but rather an older thermal pulse. The Kayrunnera is the oldest isotopically dated occurrence, giving an Early Permian age of $\sim$ 260 m.y. Middle and Late Jurassic ages have been obtained from Eurelia, Terowie, Meredith, and Delegate. The tentative Cainozoic age assigned to the Jugiong occurrence is still under review.

In an attempt to relate the kimberlites and their associated rock types to a structural framework, a number of features were investigated. These included on and offshore structures, igneous activity, earthquake activity, general tectonics, gravity, and magnetics. Of the features investigated, onshore structures, and present-day seismic belts, appear the most significant. Two prominent belts of earthquake activity are apparent; one strikes north to northwest through the Flinders Range in South Australia, and extends to the northwest margin of the continent; the second belt trends north through Tasmania, across Bass Strait into Victoria, thence northeastwards, into New South Wales, and continues offshore near southeastern Queensland. The South Australian occurrences all lie on the continental projection of the oceanic fracture zone arising from present-day spreading associated with the Antarctic Ridge. It is possible that this feature accords with the hypothesis that lines of weakness in old continental crust determine sites for the development of transform faults.

It is suggested that this concept may also have application to the southeastern Australian margin. On the eastern seaboard, the southern spreading ridge is thought to be responsible for the projected continental fracture zone which coincides with a broad belt of Cainozoic igneous activity, and is also approximately the edge of Cainozoic epeirogenic uplift, and the Cainozoic mean line of hot-spot migration. All the kimberlitic occurrences near the eastern seaboards of Australia fall within this broad zone of activity, but any causal connection between the Mesozoic age of intrusion and Cainozoic volcano-tectonic activity is not clear.

It is suggested that the location of kimberlitic intrusives was governed by fracture patterns developed before the formation of the Tasman Sea, which later became the sites of continental extensions of transform faults during the opening of the Tasman Sea. This seafloor spreading started 80 m.y. ago and ended 60 m.y. ago. However, the diminished number and revised distribution of transform faults in the Tasman Sea, compared with the previous number of orientations makes any conclusions concerning onshore extensions and influence of oceanic transforms uncertain.

Palaeogeotherm

All P-T estimates for the nodular assemblages from southeastern Australia indicate high temperatures of equilibration, producing steep palaeogeotherms actually exceeding the mean oceanic geotherm. The abnormally high geothermal gradients implied by these data, taken with the postulated shallow levels of kimberlite generation (60-70 km), make it unlikely that diamondiferous kimberlites of Permian or younger age will be found in southeastern Australia - except at the Eurelia (South Australia) locality, where magma compositions suggest greater depths of formation (>125 km).

Conclusions

Kimberlite generation is thought to take place near the lithosphere-asthenosphere interface, representing a small degree of partial melting of a peridotitic source rock. Emplacement of kimberlitic magma is confined to continental areas and appears to be related to uplift with attendant warping and fracturing. These fundamental structures control the emplacement of the kimberlitic magma into the base of the lithospheric plate, but, at high crustal levels, restricted scale structures control the emplacement. The superposed ancillary structures tend to mask the nature of the fundamental structures. The presence of earthquake epicentres may help in delineating the fundamental fracture zones which are still active or have been reactivated. Igneous activity associated with kimberlites in space and time includes carbonatites, alkali ultramafic magmas, and some of the more evolved mafic and salic alkaline magmas.

Although kimberlites have a wide dispersion in continental terrains, the diamondiferous ones are confined to areas of stable cratons which have not undergone an orogenic phase in the past 1500 m.y. The presence of the right tensional regime superposed on old cold cratons produces the optimum conditions for the generation of kimberlites that originate within the diamond stability zone.

GOAT PADDOCK CRYPTOEXPLOSION STRUCTURE, WA, by John Ferguson & A.L. Jaques

This project is being jointly undertaken with J.E. Harms (BHP), D.J. Milton (USGS), D.J. Gilbert (BHP), W.K. Harris (Western Mining Corporation), Bruce Goleby (ANU) and R.F. Fudali (Smithsonian Institution).

Goat Paddock, a crater slightly over 5 km in diameter (18°20'S, 126°40'E), lies at the north edge of the King Leopold Range/Mueller Range junction in the Kimberley district, Western Australia. It was noted as a geological anomaly in 1964 during regional mapping by the Bureau of Mineral Resources, Geology and Geophysics and the Geological Survey of Western Australia. Two holes were drilled by a mining corporation in 1972 to test whether kimberlite underlay the structure. It is now established that Goat Paddock is a cryptoexplosion crater containing shocked rocks and an unusually well-exposed set of structural features. The structure has been mapped at a scale of 1:10 000 and two detailed gravity and magnetic traverses completed.

Goat Paddock is a circular plain bounded for most of its circumference by steep cliffs 100-150 m high. To the north, the rim has been eroded, opening a broad connection with the valley of the O'Donnell River. To the south and east, the ground is higher and more rugged, so that a raised rim is not evident. The circularity of the rim is reduced by erosion and by the presence of remnants of crater fill within the wall. Its topography is clearly unusual but not immediately suggestive of a crater.

The two drillholes, one at the centre and one about 1250 m northeast of the centre, penetrated 211 and 212 m of lacustrine sediments, of probable early Eocene age, before entering brecciated sandstone. The nearly equal depths suggest the absence of a central peak, which might have been expected as the critical diameter for the transition from simple to complex terrestrial cryptoexplosion crater [illegible] 2-3 km in sedimentary strata and about 4 km in crystalline rocks. The fine-grained nature of the mudstone at the base of the crater fill, immediately above untransported breccia in both drillholes does, however, suggest that there may be a moat in the outer crater floor that acted as a trap for coarse debris. The small depth/diameter ratio is closer to those of larger, complex craters than to those of smaller, simple craters.

The canyons eroded into and through the walls of Goat Paddock offer some of the best exposures of the upper rim wall and rim flank of any cryptoexplosion crater in the world. Nearly everywhere in the walls, bedrock has been upturned from its regional dip of 15° north-northwest to dip away from the crater. Dips reach the vertical near the crater lip and are overturned to the horizontal or inverted outward on the rim flank. In some sections, the rim flank appears to be composed of moderately dipping and presumably overturned imbricate plates a hundred metres or so across which are separated by screens of breccia. The rocks are intensely disturbed as far as 800 m from the present rim crest. At one locality, a fault surface with a dip of 75° towards the crater and with striations pitching 75° separates undisturbed sandstone from overturned sandstone. The sense of motion on the fault was not determined: it may be either a thrust fault or a normal fault produced by slumping of the rim into the crater. On the south rim, no overturned flap is apparent, but the autochthonous rock is deformed into at least one open anticline.

The disturbed beds show a high degree of fracturing everywhere and grade into breccia inside and particularly outside the rim crest. At many breccia occurrences, attitudes of the larger clasts are close to those of nearby coherent bedrock, and the lithologies are the same, showing that little mixing or long-distance transport has taken place. On the south rim, a series of ridges ~20 m high have fractured bedrock at the base and breccia at the top. No fall-out (air-sorted debris) was found on the rim, and we are uncertain whether the breccia at high levels on the rim includes throw-out (debris ejected ballistically).

Goat Paddock is clearly a cryptoexplosion crater, of a type generally attributed to meteorite impact. Nevertheless, in the absence of meteoritic material, hypotheses of endogenous origin are defensible. The 875 m diameter Wolf Creek Crater, which is only 160 km to the southeast, is associated with oxidised meteoritic iron, although the association could be coincidental. Wolf Creek seems to be less eroded than Goat Paddock, so an age as old as Eocene and a paired relationship seems unlikely although not impossible. About the same distance northwest of Goat Paddock is another cryptoexplosion structure, known as 'The Spider', which we have also briefly examined. Disturbed and shatter-coned strata occupy an area about 5 km in diameter. The structure resembles that of central uplifts of other cryptoexplosion structures and is apparently exposed at a level considerably below an original crater floor. The depth of erosion indicates an age greater than that of Goat Paddock. The Spider and probably Wolf Creek are in tectonically stable blocks, but Goat Paddock lies near the intersection of the King Leopold and Halls Creek Mobile Zone, which have been intermittently active through geological time. Adjacent to the King Leopold Mobile Zone is a major province of salic alkaline igneous intrusion dated as early Miocene; this province, and an area adjacent to the Halls Creek Mobile Zone, have also recently been identified as areas of major kimberlite intrusion of unknown age.

STRANGWAYS CRYPTOEXPLOSION STRUCTURE, NT, by John Ferguson

This project is being jointly undertaken with R. Brett (National Science Foundation, USA); M.R. Dence (Department of Energy, Mines & Resources, Canada); D.J. Milton (USGS); C.H. Simonds (Northrop Services Inc., USA), and S.R. Taylor (Australian National University).

STRUCTURE

As a first stage in a geological-geochemical study of this previously barely known cryptoexplosion structure, a geologic map has been prepared by a series of Landrover traverses supplemented by photogeology. The disturbance, centred near 15°12'S, 133°35'E, is in a region of faulted and gently folded quartzites and siltstones of the Middle Proterozoic Roper Group. The margins of extended areas of Cambrian, Cretaceous, and Cainozoic strata each pass near the site. Flat-lying Cretaceous sandstone conceals about a quarter of the structure. Middle Cambrian limestone, poorly exposed and near the edge of the structure, probably but not certainly postdates the disturbance.

The basic structure is the core-and-collar type known from the Vredefort Ring. The core, about 10 km in diameter, consists of basement rock, mainly granitic gneiss, which otherwise does not crop out within 100 km and should lie at a depth of over 1 km. The ground surface is a plain that approximates the base of the melt layer; most exposures are of breccia (generally highly shocked), melt rock is common, and unbrecciated bedrock was not definitely identified. A drillhole sited on a 15 m hill started in vesicular melt rock with less than 5 percent clasts and bottomed at 30 m in melt with about 60 percent clasts. Melt at most occurrences appears (to hand-lens study only) to be derived from basement and to contain basement clasts; some also contains clasts from the Roper Group. Drill core from a shallow hole near the basement-Roper Group contact shows clasts of quartzite, presumably from the ~200 m thick basal unit of the Roper Group, in a melt that may derive from siltstones even higher in the section.

The collar, generally about 5 km wide, consists of Roper Group quartzites and siltstones in alternating ridges and valleys. In some sectors quartzite units extend outward from a vertical or steeply dipping outward-facing root zone into a flap that overlies the succeeding siltstone. The lowermost quartzite is largely autochthonous breccia in the root zone (megaclasts retaining their attitude among unoriented small clasts) and unoriented breccia in the flaps. Brecciation is minor in the higher quartzites - some of the flaps are flat-lying and look almost undisturbed except that they are upside down. In one sector a flap of an outer quartzite extends over 3 km from the root zone to a distance of nearly 12 km from the centre. This is probably about the radius of the disturbance. Shatter fracturing, more commonly expressed as intersecting sets of striated cleavage surfaces rather than as well-formed cones, is well displayed in the inner quartzites but poorly developed both toward the outside of the collar and in the gneiss.

PETROCHEMISTRY

Chemical changes have been documented for the three main rock types encountered in the area, namely, shales, quartzites, and granitoids. Shales and quartzites of the Roper Group were sampled outside the areas of disturbance and compared and contrasted with their shock-metamorphosed equivalents. The disturbed quartzites include fractured and brecciated, including mylonitised, samples. The shock-metamorphosed shales all include a melt component which, in some samples, can be extensive. As there is no coherent bedrock exposed in the core the least disturbed granitoid gneisses show varying degrees of shock metamorphism, which includes shatter-cones, rhomb-cleavage, planar decorations in quartz, and sundry brittle fracture and brecciation. The composition of these rocks is similar to granitoid equivalents that have undergone varying degrees of melting frequently accompanied by brecciation. The shock-melt granitoids were arbitrarily subdivided into two subgroups based on whether the melt component was above or below 50 percent.

A number of sympathetic chemical changes is shared by the quartzites, shales and granitoids in their transformation from unshocked or moderately shocked rocks into shock-melt or brecciated equivalents (Table M2). Si is the only element removed whereas chemical additions are recorded by three major elements and eleven minor and trace elements. Metasomatic changes that are not common to all three rock types but which are recorded within individual suites are shown in Tables M3, M4, and M5.

Granitoids

Four subgroups of granitoids were distinguished: the least shocked, brecciated, and brittle-fractured material forms one subgroup; ultrabrecciated mylonitic material (pseudotachylite) forms a second subgroup; the shock melts were placed in two subgroups - those above and below a 50 percent melt component. Not surprisingly the pseudotachylitic rocks have similar chemistry to the least shocked granitoids. The granitoids exhibiting varying degrees of melting offer large chemical contrasts to the least shocked material (Tables M2 and M3): Si is the only element to decrease during progressive shock metasomatism. Not surprisingly this major change in Si results in most of the other major elements increasing, in particular this holds for Al, Mg, and K. Of the minor and trace elements to show strong sympathetic additions (in excess of five times) are Ti, Nb, V, Cr, Ni and W (Tables M2 and M3). The less than 50 percent melt granitoids generally exhibit element concentrations intermediate between the greater than 50 percent melt granitoids and the other two subgroups.

Table M2. Element migration accompanying the change from unshocked or moderately shocked quartzites, shales, and granitoids to shocked melts (shales and granitoids and breccias

Removal

Lithophile Si

Addition

Lithophile Ti Al Mg K Ba Y La Ce Cr W

Siderophile P Co Ni

Chalcophile Zn

Table M3. Element migration accompanying the change from moderately shocked to shocked granitoid melts

Removal	
Chalcophile	Cu (1 value only)
Addition	
Lithophile	Mn Zr Nb V Ga
Siderophile	ΣFe

Shales

Unfortunately only one undisturbed shale sample was analysed; this composition was compared with the shocked shale-melt material. These changes are documented in Tables M2 and M4. A marked feature of the shale-melts is that their composition is almost identical with the granitoid melt subgroups - in particular those granitoids that have a greater than 50 percent melt fraction. Where the shale-melts depart from these high-percent melt compositions, all average values, except W, lie intermediate to the two subgroups of granitoid melts. W is only marginally higher in the shale-melt compared with the compositions of granitoid subgroups containing melt fractions.

Table M4. Element migration accompanying the change from unshocked to shocked shale melts

Removal	
Chalcophile	Cu As
Addition	
Lithophile	Ca Na Rb Sr Th Nb V Ga

Table M5. Element migration accompanying the change from unshocked to shocked quartzitic breccias

Removal	
Siderophile	ΣFe
Chalcophile	As Pb
Addition	
Lithophile	Ca Na Rb Sr Th U Zr
(all of these elements are erratic)	

Quartzites

As already pointed out the shales, quartzites, and granitoids show some remarkably sympathetic metasomatic trends when progressing from the unshocked or mildy shocked state into intensely shocked equivalents (Table M2). Table M5 documents the elements in the quartzitic rocks that do not show sympathic variations with all three major rock groups. Additionally the quartzitic breccia material shows some similar geochemical trend to that of the pseudotachylite.

Conclusions

The metasomatic changes that are common to the three major rock groups, namely, shales, quartzites, and granitoids (Table M2), indicate high element mobility in the absence of melting (the quartzites show no evidence of having melted). Presumably the introduction of these elements would be associated with a vapour phase.

The almost identical composition of the shale and granitoid melt rocks, both in major and trace-element chemistry, is of interest. In a few cases of extensive melting it is difficult to petrographically distinguish a shale melt from a granitoid melt, but in most of the shale melts shaly clasts are present, thereby confirming that there is at least a shaly component. The similar chemistry of the shale and granitoid melts suggests a thorough mixing of the vapour phase and the parent rock to produce similar end products from different starting materials.

Of the elements that demonstrate sympathetic changes in the three major rock groups (Table M2) it is of interest to note that some belong to the compatible-element suite - namely, Cr, Co, Ni, and W - whereas others belong to the incompatible-element suite - namely, Ti, Ba, La, Ce, and P. Other large-scale metasomatic introductions also include K, Mg, Al, Y, and Zn. Although the compatible elements could be attributed to volatilisation of a meteorite during impact, the introduction of K and the incompatible elements would not support such an origin. If the shock-metamorphism observed is to be attributed to a terrestrial origin, a violently explosive cryptovolcanic event would be the most likely cause. The chemical changes recorded would suggest involvement of a volatile-enriched alkaline ultramafic magma.

BMR-HOLLMAYER METEORITE STUDY by A.L. Jaques

A collaborative study with M.J. Fitzgerald (Adelaide University) was commenced to describe and classify 57 previously undescribed meteorites held in the BMR Museum. The majority of these meteorites were collected by W. Hollmayer, who donated a portion of the meteorites to BMR for study. The other meteorites were collected by D. McColl (formerly BMR) in 1974-75.

Petrographic examination and microprobe study has shown that the meteorites described to date belong to different groups and different petrologic types. Most are olivine-bronzite chondrites (H and L group) varying considerably in their degree of equilibration, corresponding to petrologic groups 4 to 6.

The most significant results to date are the discovery of a carbonaceous meteorite (Tibooburra) and an unusual brecciated meteorite (Nilpena). Detailed study of Tibooburra shows that it contains chondrules and crystal aggregates of forsteritic olivine Fa_{17-0} (mostly Fa_{9-0}) and clinoenstatite with some pentlandite in a dark carbonaceous matrix. The meteorite also contains Ca-Al-Ti-rich inclusions containing anorthite, diopside, spinel (pure $MgAl_2O_4$), ilmenite, and fassaitic pyroxene as well as olivine (Fa_{13-0}), enstatite, and magnesian pigeonite. The texture and mineralogy suggest that Tibooburra is a type III carbonaceous meteorite of the Vigarano subgroup. Chemical analysis of the meteorite for major elements, carbon, and sulphur is currently being undertaken at Adelaide and the Research School of Earth Sciences, Australian National University, to enable more precise classification of the meteorite.

Nilpena is a polymictic breccia containing clasts of different meteorite types. The most conspicuous clasts are medium-grained allotriomorphic granular aggregates of olivine Fa_9 and pigeonite $Ca_{10}Mg_{75}Fe_{15}$ with interstitial metallic Fe and troilite. Other clasts include chondrules containing porphyritic olivine and clinobronzite, granular olivine chrondules, crystal fragments, (olivine and pigeonite), clinoenstatite chondrule fragments, and an achondritic fragment of fine-grained augite, calcic plagioclase (An_{98}), and olivine (Fa_{50}). The clasts are set in a matrix of metallic iron (intensely oxidised) with fragments of olivine and pigeonite and Ca-poor pyroxene. Chemical analysis of the meteorite is in progress.

TUREE CREEK URANIUM MINERALISATION, WA, by John Ferguson

At Turee Creek a major unconformity separates the Lower Proterozoic Wyloo Group and Middle Proterozoic Bresnahan Group. High radiometric anomalies have been confirmed along a seven-kilometre section of a fault zone separating these two groups of Proterozoic rocks. Trenching and drilling has been undertaken to assess the importance of the radiometric anomalies. Mapping and sampling has been undertaken with a view to understanding the controls of uranium mineralisation within the area.

GRANITES OF THE MOUNT ISA INLIER by L.A.I. Wyborn

This project commenced in July 1978 with the aim of investigating the geochemistry of the granites of the Mount Isa Inlier, their intrusive history, the nature of the deep crust in the Mount Isa Inlier, and the relations between granites and ore deposits in space and time. Complementary investigations were to include geochronology, geophysics, and the relation between granites and felsic volcanics and metamorphism. The study was suspended from October 1978 to January 1980 whilst L. Wyborn was on leave.

During the 1978 field season it was not possible to sample all of the Duchess/Urandangi 1:250 000 Sheet areas, so a further 200 samples were submitted for chemical analysis from collections made by R.J. Bultitude, D.H. Blake, and A.L. Jaques, and from age determination samples collected by R.W. Page. All chemical data available for the Mount Isa Inlier - amounting to 1300 analyses - have been collated on the 9825A Hewlett Packard computer system using programs written by M. Owen. These analyses are of granites, felsic and mafic volcanics, and sedimentary rocks from the Corella Formation and Marimo Slate.

Preliminary results of the project are as follows:-

1. The granites of the Mount Isa Inlier are either I-type, derived by partial melting of deep crustal igneous material, or A-type, derived by partial melting of deep crustal, near anhydrous, granulite facies material also of igneous origin.

Petrographically the I-types are characterised by abundant plagioclase, many crystals of which have distinct cores, and biotite + sphene + magnetite $\pm$ hornblende. The A-types have a lower plagioclase content and generally have higher SiO_2 contents, and commonly contain a pale green clinopyroxene in the more mafic varieties. The I-types range from tonalites through granodiorites to adamellites to granites (sensu stricto), whereas the A-types are mostly alkali feldspar granites, or granites (sensu stricto), or adamellites. The I-types are represented by the Naraku, Kalkadoon, Big Toby, and Hardway Batholiths, and parts of the Sybella, Wonga, and Williams Batholiths. A-types include the Burstall, Weberra, Wimberu, and parts of the Williams, Wonga, and Sybella Batholiths.

All I-types are restite controlled. They are characterised by inverse linear trends for most elements when plotted against SiO_2, and have high ratios of Fe_2O_3/FeO, particularly the Naraku Batholith. Hornblende, apatite, zircon, and plagioclase cores are mostly regarded as xenocrysts. Samples of the Wonga and Naraku Batholiths are distinguished by higher Zr, Nb, Th, Y, and lower Sr contents than the Hardway, Kalkadoon, and Big Toby Batholiths.

Chemically the A-types have exceptionally high Zr, Nb, La, and Ce contents and very low CaO, Al_2O_3, and Sr values.

The granites of the Mount Isa Inlier are all abnormally low in Cr and Ni, and this combined with their vast volume relative to mafic rocks and the paucity of rocks of intermediate composition precludes their derivation by direct partial melting from the mantle. Instead they are probably derived from deep crustal material of intermediate composition which has never been exposed at the Earth's surface. The I-types represent the removal of a hydrous melt from this material and the A-types are remelts of the near-anhydrous residue left behind after the removal of the hydrous melts.

Using felsic volcanic analyses collected by I. Wilson, R. Bultitude, D.H. Blake, G.M. Derrick, and A.L. Jaques, and comparing them with the granite analyses, the following results have been noted.

Felsic volcanics mapped as Standish Volcanics in the Duchess 1:250 000 Sheet and Leichhardt Metamorphics are similar in chemistry and are comagmatic with the Kalkadoon Batholith. The Bowlers Hole Granite is the only pluton identified so far that is comagmatic with the Argylla Formation, and the Fiery Creek Volcanics are comagmatic with the Weberra granite. Limited data on the Carters Bore Rhyolite suggest that it is similar to parts of the Sybella Batholith. Felsic volcanics in the Corella Formation are of diverse compositions: those near Duchess are comagmatic with the Bushy Park Gneiss and those in the Selwyn region may be comagmatic with the Williams Batholith.

PILBARA VOLCANIC GEOCHEMISTRY: PHASE 1

by A.Y. Glikson & A.H. Hickman (GSWA)

The first phase of a geochemical investigation of the Archaean volcanic successions of the Warrawoona Group and Gorge Creek Group in the eastern Pilbara Block will be reported in a joint Record (in prep.) on the basis of 442 volcanic rock samples analysed for major elements, Ba, Rb, Sr, U, Th, Zr, Nb, La, Ce, Y, Li, Ni, Co, Cr, V, Cu, Zn, Ca, and S. The results allow the construction of a regional geochemical-stratigraphic framework for volcanic successions in the eastern Pilbara Block, facilitating the use of whole-rock geochemical parameters as criteria for stratigraphic identification of isolated volcanic rock bodies. A screening method for altered samples was designed using LMPR (log molecular proportion plots), and data of least-altered rocks were computed for magmatic fractionation models and mantle composition. The data reveal vertical trends significant to evolution of the Archaean mantle and to secondary redistribution patterns associated with alteration. Concomitant migration of volatiles (H_2O and CO_2), alkalies, sulphur, and copper toward the tops of individual volcanic sequences is indicated, together with implications about the development and spatial controls of base metals.

The geochemical study allows an insight into the petrogenesis of the Archaean crust. The 3560 ± 32 m.y. old Talga-Talga Subgroup (Hamilton & others, in press)* is dominated by tholeiitic basalt and dolerite of high Ti and low K, Al, Ni, and Cr. High-Mg basalt, peridotitic komatiite, and lenses of high-Al dacite-andesite are interspersed with the tholeiites. The overlying Salgash Subgroup consists of a lower basic unit which includes peridotitic komatiites (Apex Basalt), an upper unit of tholeiitic to high-Mg basalts (Euro Basalt), and intervening dacite-rhyolite lenses (Kelly and Panorama Formations). Tholeiitic basalt units in the overlying sedimentary Gorge Creek Group (Charteris Basalt, Honeyeater Basalt) have high K and Al and low Ti. A progressive depletion in Fe, Ti, P, Zr, and Y is shown by tholeiitic basalts, constituting both an overall trend and repeated smaller-scale cycles. These trends cannot be explained by magmatic fractionation, and reflect either secular mantle depletion owing to repeated partial melting events and/or progressively deeper melting in a geochemically zoned low-velocity zone. The alteration screening method using LMPR indicates considerable mobility of alkali and alkaline-earth elements and relative stability of siderophile (Fe, Ti, Mn, V), some LIL (P, Zr, Nb, Y), and magnesia-related volatiles, alkalies, and Cu. These are attributed to either synvolcanic carbonatisation and/or secondary leaching. Petrogenetic calculations suggest iron-rich mantle source compositions (Mg numbers in the range 80-90). Peridotitic komatiites formed by over 50% melting of mantle peridotite, possibly representing high-temperature diapiric events. Compositional gaps between peridotitic komatiites and high-Mg basalts suggest that they are unlikely to be related by crystal fractionation. A continuous chemical spectrum between high-Mg basalts and tholeiitic basalts is consistent

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*In Geological Society of Australia, Special Publication.

with the latter having formed from the former by fractionation of clinopyroxene, olivine, orthopyroxene, and minor plagioclase.

Collaboration with laboratories in the USA and France resulted in new contributions, including a study of rare-earth elements and isotopes in silicic volcanics (Warrawoona Group) and of granites by Bor-ming Jahn, University of Rennes, France, and a Sm/Nd isotopic study of samples of North Star Basalt (Talga-Talga Subgroup) by P.J. Hamilton, Lamont Doherty Geological Laboratory, Columbia University, New York.

In the isotopic rare-earth elements study, 18 silicic volcanic rocks of the Warrawoona Group and 10 associated plutonic rocks were studied. The silicic volcanics of the upper member of the North Star Basalt are dated at 3560-3570 m.y. by both Rb-Sr and Sm-Nd. The I_{Sr} value is 0.7005 $\pm$ 5 and I_{Nd} value is 0.50810. This age is consistent with the stratigraphic relations between the Talga-Talga Subgroup and the overlying Duffer Formation, whose age was established at 3450 m.y. by U-Pb zircon (Pidgeon, 1978). The new Rb-Sr data on 6 silicic lava samples yield an isochron of 3230 $\pm$ 280 m.y. with I_{Sr} = 0.7007; this agrees within narrow limits with the U-Pb zircon age. The ages of 2300-2400 m.y. obtained for the Panorama Formation and Wyman Formation do not correspond to initial igneous ages. Chemical arguments suggest that these ages represent the time of metasomation associated with the widespread thermal event in the Pilbara at 2300-2400 m.y. Geochemically, most of the analysed volcanic and plutonic rocks are of trondhjemite to granodiorite composition, a typical feature of Archaean terrains. They generally show fractionated REE patterns, except for the Panorama rocks. Furthermore, the Wyman Formation rhyolites and the post-tectonic adamellites show significant Eu negative anomalies, suggesting a similar mode of magma generation and a probable genetic link. Theoretical considerations suggest that most of the sodic silicic rocks were generated by partial melting of amphibolitic or basaltic sources, followed by fractional crystallisation. Although the Archaean granitic gneisses often possess mantle-like I_{Sr} values, the trace-element data suggest they could not have been derived by direct melting of upper mantle material. The immediate tectonic implication is that in any Archaean terrain the formation of sodic silicic crust must be preceded by the presence of basaltic crust. The nature of this basaltic crust is controversial: it may have been totally destroyed by repeated melting processes, or its upper level remnants are represented by mafic-ultramafic enclaves with the trondhjemite batholiths.

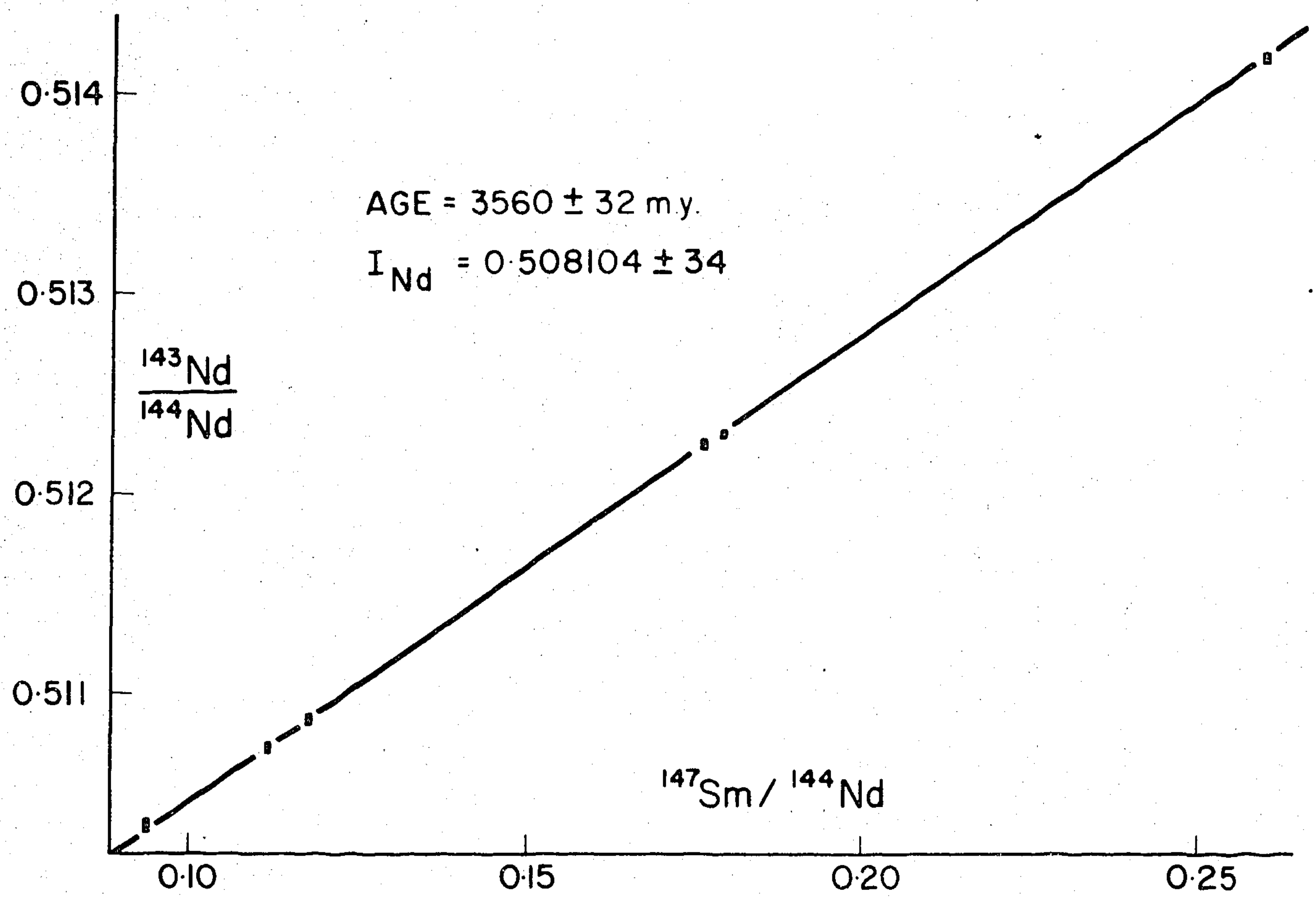

Fig. M 11a Sm - Nd isochron for 6 samples of the North Star basalt, Warrawoona Group, Marble Bar area, eastern Pilbara, W.A.

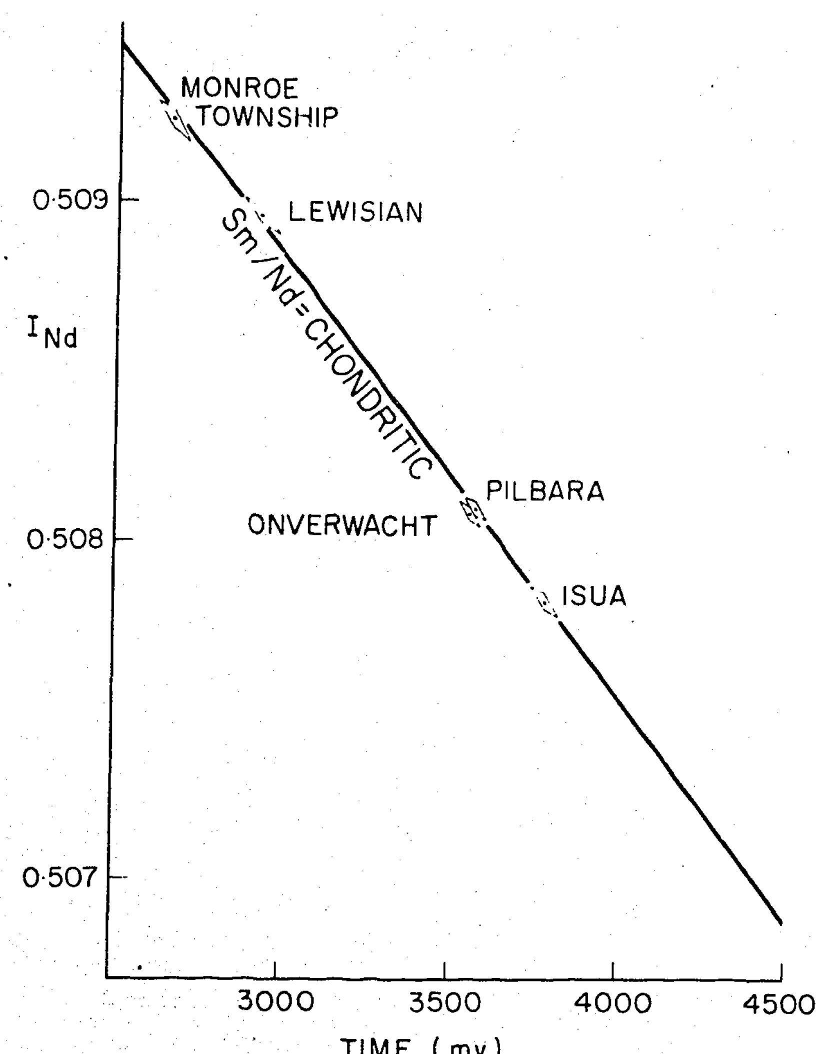

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Fig. M 11b Initial Nd^{143}/Nd^{144} (I_{ND}) plotted against time, for Pilbara, Onverwacht, Isua, Lewisian and Monroe Township samples.

Sm-Nd isotopic study of the North Star Basalt yielded a precise isochron of 3560 ± 32 m.y. (I_{Nd} = 0.508104). This isochron is based on analyses of six samples, including one komatiite, two high-Mg basalts, one andesite and two dacites (Fig. M11a). They form a perfect fit to a least squares regression line. The age is thought to represent the original volcanic activity. The result is remarkably similar to the Sm-Nd age of 3540 ± 30 m.y. and I_{Nd} of 0.50809 ± 0.00004 of the lower Onverwacht Group, Transvaal, South Africa (Fig. M11b). Had the mantle source region of the North Star Basalt evolved in a single stage from 4500 to 3560 m.y., starting with an I_{Nd} ratio equal to achondrites, then the time-integrated Sm/Nd ratio is 0.308 ± 0.004 (Fig. M11b). This ratio is similar to those determined for single-stage evolution of mantle sources of other Archaean igneous suites.

The results of the Pilbara geochemical study were read at the 2nd International Archaean Symposium in Perth, May 1980. Publications are in press in the Symposium volume. A paper based on the REE and isotopic study of silicic volcanic rocks and granites by Jahn & others has been submitted to Geochimica Cosmochimia Acta. Analyses of peridotitic komatiites, high-Mg basalts, and tholeiitic basalts from the Warrawoona Group and Gorge Creek Group are in progress.

PILBARA VOLCANIC GEOCHEMISTRY: PHASE II by A.Y. Glikson, R. Davy (GSWA), & A.H. Hickman (GSWA)

After examining and discussing the results of Phase I, BMR and the Geological Survey of Western Australia agreed to expand the scope of the study to include Archaean greenstones in the central and western parts of the Pilbara Block, as well as upper Archaean-Lower Proterozoic volcanics in the eastern Pilbara. The geochemical data base would thus cover most of the stratigraphic column of the northern Pilbara Block, including the Warrawoona Group, Gorge Creek Group, Whim Creek Group, and Fortescue Group. The total data by the end of Phase II would include approximately 1000 detailed chemical analyses, providing a suitable basis for the study of geochemical changes associated with base-metal and precious-metal mineralisation processes.

The sampling campaign was undertaken jointly by A.Y. Glikson and R. Davey during August-September, 1980. At the outset, candidate sections were visited and examined jointly with A.H. Hickman, the GSWA's regional geologist. After the selection of suitable areas, sampling traverses were carried out in areas shown in Figure M12 as follows:

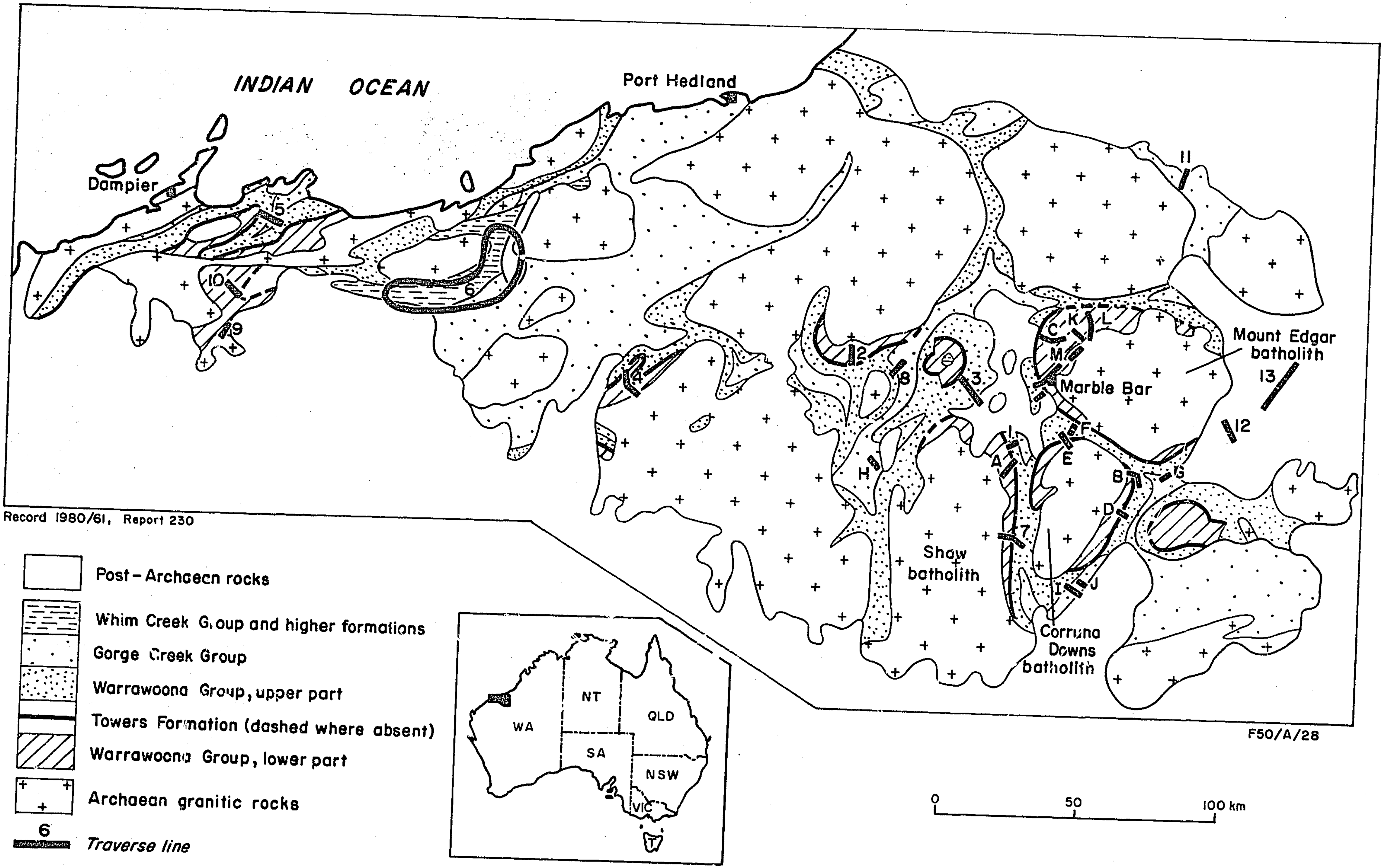

Fig. M12 Pilbara sampling traverses, phases I and II

FIG. M12 - PILBARA SAMPLING TRAVERSES, PHASES I AND II

Key to locality numbers

A	Sharks centre	
B	Sandy Creek	
C	Bowls Gorge	
D	Spinaway Creek	
E	Camel Creek (Apex and Euro Basalts)	
F	Camel Creek (Wyman Formation)	Sampled by
G	Charteris Creek	GSWA, 1976
H	Soanesville	
I	Budjan Creek	
J	Emu Creek	
K	Talga Talga centre	
L	Talga River	Sampled by
M	The Sisters - Coongan Creek	BMR, 1975
1	Sharks Centre	
2	Pilgangoora	
3	North Pole	
4	Hong Kong - Pilbara Well	
5	Roebourne	
6	Whim Creek	
7	Withnells Creek	
8	Northeast Strelley	Sampled by
9	Whundoo	BMR and GSWA,
10	Mount Scholl	1980
11	Shay Gap	
12	Pelican Pool	
13	Meentheena	
14	Davis River (out of map, ca 100 km east of Nullagine)	

Area	Stratigraphic unit	Worker	Number of samples (o sampling stations)
(1) Fortescue Group			
David River (Hays Ck)	Kylena Basalt,) Nymerina Basalt) Maddina Basalt)	AYG and RD	89
Meentheena (Nullagine River)	Kylena Basalt) Nymerina Basalt) Maddina Basalt)	AYG	38
Pelican Pool	Kylena Basalt)	AYG	24
Yandicoogina	Mt Roe Basalt)	RD	23
Glen Herring	Mt Roe Basalt)	RD	25
			total - 199
(2) Whim Creek Group			
Pyramid Road	Warambie Basalt	AYG	9
Warambie Homestead	Warambie Basalt Louden Volcanics	AYG	11
Whim Creek area	Louden Volcanics	RD	50
"	Mt Negri Volcanis	RD	26
"	Mons Cupri Volcanis	RD	18
"	Mt Brown Rhyolite	RD	16
			total - 130
(3) Gorge Creek Group			
Shay Gap	Honeyeater Basalt	RD	21
Strelley Gorge	Honeyeater Basalt	RD	10
			total - 31

(4) Warrawoon Group

Withnell's Creek	Talga-Talga Subgroup)		
	Duffer Formation)	AYG	46
	Salgash Subgroup)		
Tambourah	possible Talga Talga Subgroup	AYG	25
Sharks	Duffer Formation	AYG	21
Bamboo Creek	Salgash Subgroup	RD	27
Pilgangoora	Talga-Talga Subgroup)		35
	Salgash Subgroup)	RD	22
North Pole	Salgash Subgroup	RD	60
Pilbara Well	Salgash Subgroup	AYG	11
Cleaverville	Salgash Subgroup	AYG	20
Karratha	Salgash Subgroup	AYG	14
Mt Sholl	Duffer Formation	AYG	17
Whundoo	Talga-Talga Subgroup	AYG	23
		total -	321

Out of the total sample population of 681 about 500 will be selected for analysis for major elements, Ba, Rb, Sr, Pb, Th, U, Zr, Nb, Y, La, Ce, Li, V, Cr, Co, Ni, Cu, Zn, Ga, S, and CO_2. The data will be stored on magnetic tape and processed according to programs written for Phase I of the project, as well as new programs to be written.

PRECAMBRIAN GEOTECTONICS - PUBLICATIONS AND OVERSEA VISIT by A.Y. Glikson

A paper entitled 'Precambrian sial-sima relations: evidence of Earth expansion' appeared in Tectonophysics, and considered the apparent scarcity of evidence for simatic crust during 2600-1200 m.y. ago, particularly in the light of geochemical, isotopic, and palaeomagnetic data. The enigma arising from the geochemical and isotopic data has been reinforced by the palaeomagnetic synthesis of Embleton & Schmidt (1979)*. A discussion with regard to this problem appeared in Geology ('The missing Precambrian crust - comment and reply', by A.E. Baer & A.Y. Glikson). Methodological and philosophical aspects of Precambrian research were considered in an invited paper for the volume Precambrian Plate Tectonics (ed. A. Kroner), entitled: 'Uniformitarian

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*Nature, 282, 705-7.

assumptions, plate tectonics and the Precambrian Earth'. During April a trip was undertaken (while on leave) to visit universities and government institutions in the USA to discuss problems of Precambrian tectonics with interested scientists. The US Geological Survey headquarters in Reston (Virginia) were visited, as well as branches at Denver, Flagstaff, and Menlo Park. Visits were also made to and seminars given at NASA's Lunar Science Institute (Houston), Massachussets Institute of Technology, Carnegie Institute of Washington, New Mexico Institute of Mining and Technology, Scripps Institute of Oceanography, and the Universities of Tallahassee, Princeton, Pittsburgh, and Minneapolis. Physicists with whom discussions were held included Professors P.A.M. Dirac, I.I. Shapiro, and R. Dicke. The general response to the seminars and during discussion confirmed the existence of a major enigma regarding the nature of the unrecorded 2/3 of the Earth's crust during the Proterozoic. Although this enigma does not arise on an Earth of significantly shorter radius, no physical explanation for such expansion is at hand at the present state of knowledge. These questions are to be discussed in S.W. Carey's Expanding Earth conference in Sydney, February, 1981.

X-RAY DIFFRACTION by J.L. Fitzsimmons

Five-hundred-and-fifty samples were analysed by X-ray diffraction during the period November 1979 to October 1980. Ninety-seven percent of the work load was submitted by the following:

1. John Ferguson (20%) - Search for coesite/stishovite in material from Goat Paddock, Kimberley region, (NT).
2. R.V. Burne (20%) - Clays and carbonates from Spencer Gulf and the Great Barrier Reef.
3. James Ferguson (13%) - carbonates and iron oxides from Spencer Gulf.
4. P. Davies (9%) - carbonates from the Barrier Reef.
5. B. Bubela (8%) - synthetic carbonates from Baas Becking tank experiments.
6. R.D. Shaw (7%) - whole-rock samples from the Arunta sheet.
7. I. Crick (6%) - carbonate samples from the Pine Creek Geosyncline.
8. B. Radke (6%) - carbonates from Georgina basin.
9. T. Donnelly (6%) - carbonates and sulphides for isotope studies.
10. T. Zapaznik (2%) - high purity mineral separates from Antarctic granites.

In October the voltage-stabilising circuitry of the X-ray generator was successfully converted from valve to fully solid-state operation.

GEOCHEMICAL LABORATORY

ARALUEN GEOCHEMICAL PROJECT by B.I. Cruikchank

The geochemical survey of the ARALUEN 1:100 000 Sheet area commenced in the 1977-78 field season, the objects being to gain an understanding of geochemical dispersion patterns in temperate terrains and to generate data to assist future exploration in, and economic assessment of, the area. Sampling was completed in the 1978-79 season and analysis of all samples by mid-1980.

The analytical data have been coded, checked, and catalogued in the Cyber system as two work files, one containing data on some 900 soil samples and the other data on some 500 stream-sediment samples. The soil data have been merged with sampling information including location and underlying rock type and rock unit, allowing the data to be analysed in toto or to be grouped by area or underlying lithology. Stream-sediment data will be similarly classified on the basis of predominant rock type or types in the drainage basins.

Examination of the soil data shows five areas with significant anomalies in Cu, Pb, and Zn (± As, Bi and Sn), the criteria being four or more adjacent anomalous samples or two or three adjacent, highly anomalous samples. Only one of these areas appears to be associated with known mineralisation. The others are still under investigation, as an earlier interpretation that the anomalies are associated with dolerite dykes is now in question.

Preliminary examination of the stream-sediment data shows a number of areas anamalous in As (± Pb, Zn, and Sn).

GEORGETOWN GEOCHEMICAL PROJECT by P.A. Scott, J.G. Pyke

BMR has been involved with systematic regional geochemistry surveys in the Georgetown Inlier since 1972. Commencing with orientation work in 1972-73, regional stream-sediment surveys were carried out over FORSAYTH in 1974, and GILBERTON and GEORGETOWN in 1976.

Assessment of the data indicates a number of anomalies, in particular a high regional level for tin. From the initial examination of the data for FORSAYTH the high tin values appeared to be related to the Carboniferous Newcastle Range Volcanics, possibly high-level intrusives. However, the later surveys suggested the regional tin anomaly was more pervasive and included other rock units particularly Mesozoic sediments.

In order to examine the nature and extent of the regional tin anomaly and its possible relationship to Mesozoic sediments, a regional stream-sediment geochemical survey was conducted in the 1980 field season in Sheet areas to the west of FORSAYTH and GEORGETOWN as shown in Figure M13.

The survey procedures were similar to those previously adopted by BMR in the Georgetown Inlier, utilising both helicopter and ground traversing. A sparser sample density was employed, about 1 sample/5 km^2 which was increased only where geological mapping indicated areas of economic interest, such as zones of alteration, etc. Particular care was taken to obtain composite samples, and sampling also included detritus deposited in sedimentary 'traps'.

About 1800 samples were collected; they were sieved to minus 180 micrometres and the fine-fraction ground in an agate mortar. A heavy-mineral fraction was separated using a Wilfley Table.

Samples are currently being analysed for Li, Be, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Rb, Sr, Y, Zr, Nb, Mo, Sn, Ba, Ce, W, Pb, Bi, Th, U.

The current status of BMR's regional stream-sediment surveys in northern Queensland, including Sheet areas in the Georgetown Inlier, is tabulated in Figure M14.

<u>RANGER 1 BIOGEOCHEMISTRY AND SOIL GEOCHEMISTRY</u> by B.I. Cruikshank & J.G. Pyke

This project aims to evaluate biogeochemical and geobotanical methods as applied to the search for uranium in the Pine Creek Geosyncline. Botanical sampling over the then undisturbed Ranger I, No. 3, orebody and adjacent barren areas took place in 1979. At the same time, samples from an existing soil grid and soil samples from the barren areas were collected and have since been analysed.

Trial analyses on botanical samples indicated:

1) that ash from leaves of some species (e.g.,4 species of eucalypts) growing over the orebody show high levels of uranium (100-400 ppm) whereas other plant species do not (2-5 ppm)
2) that ash contents were low (ca2%), necessitating ashing of large quantities of material for U analysis by XRF.

Consequently, other methods of U analyses are being investigated, so far with mixed results.

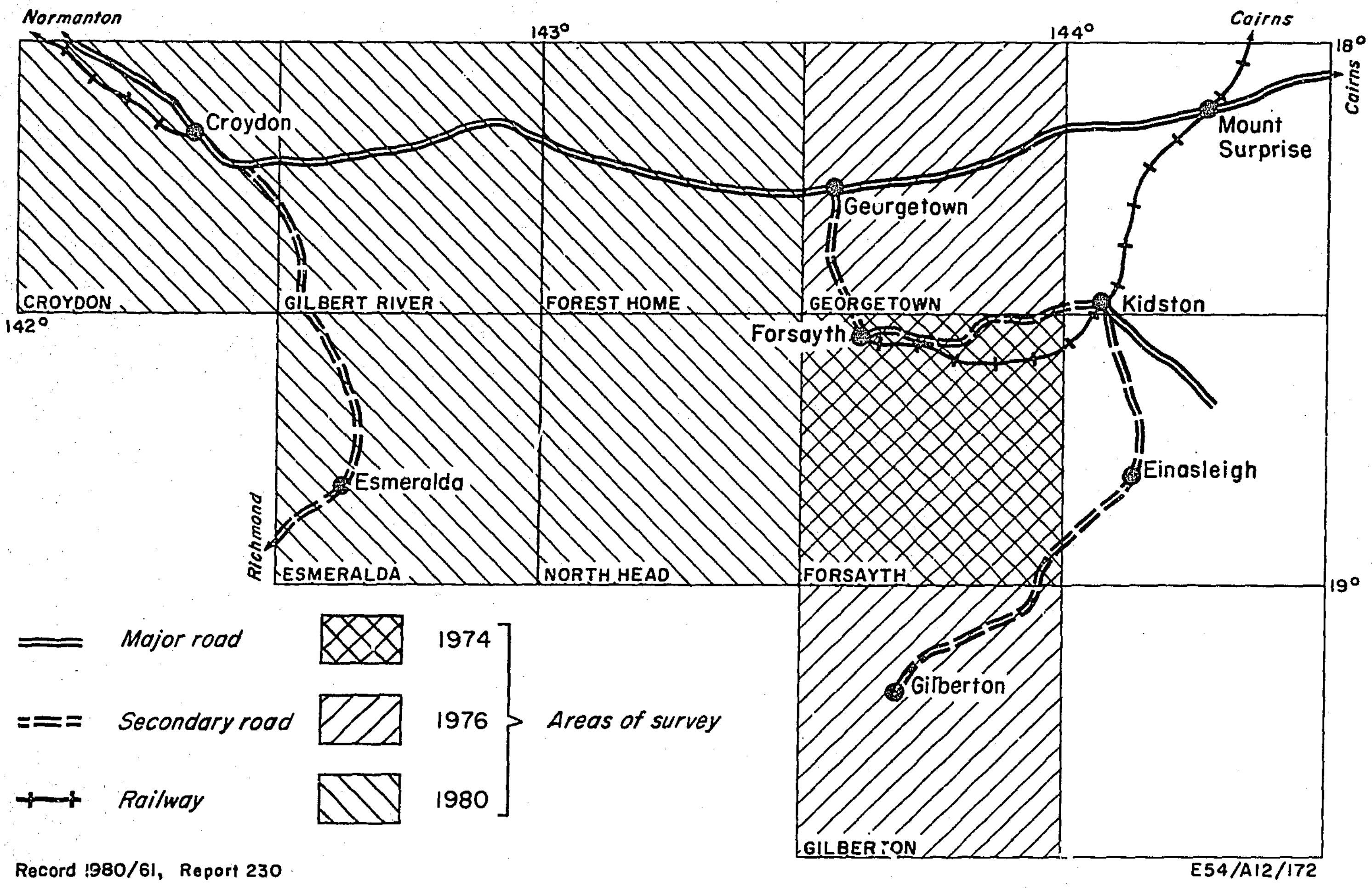

Fig. M13 Location map showing areas surveyed for stream-sediment geochemistry in the Georgetown Inlier.

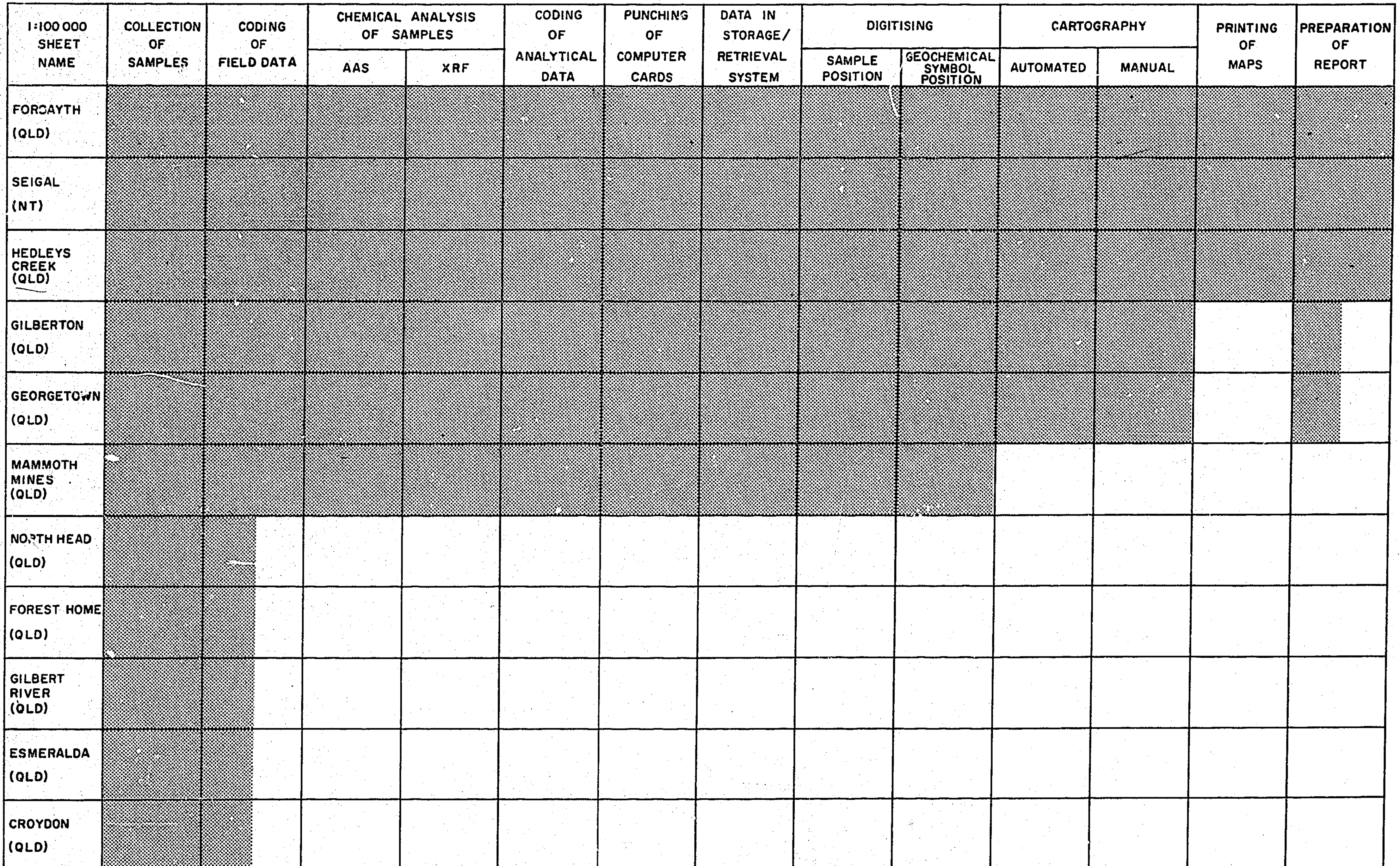

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Fig. M14 Current status of BMR's regional stream-sediment surveys.

GEOCHEMISTRY, PETROLOGY, AND GENESIS OF URANIUM ORES - NABARLEK by G.R. Ewers & John Ferguson

This project is a continuation of geochemical and petrological studies started in 1975 to investigate the controls and genesis of unconformity-related vein-type uranium deposits in the Alligator Rivers uranium field. Earlier work indicated similarities between the Jabiluka, Ranger I, and Koongarra deposits and led to the publication of a model for ore genesis (Ferguson, Ewers, & Donnelly, 1980)*. However, significant differences between these deposits and the Nabarlek deposit (e.g., at Nabarlek there is an absence of massive-bedded carbonates and a close spatial association between uraninite and hematite) do not make this and other models generally applicable. A better understanding of the genesis of the Nabarlek deposit is therefore being sought.

The collection of samples took place during the mining operation in 1979. With the cessation of mining, the open pit has become flooded and further sampling is no longer possible.

Whole-rock analysis (major elements plus As, Ba, Ce, Cu, Ga, La, Mo, Nb, Ni, Pb, Rb, S, Sc, Sn, Sr, Th, U, V, Y, Zn, Zr, Hf, Cs, CO_2, $H_2O\pm$) is well underway, but delays have been experienced due to the severe interference caused to XRF analyses (major elements in particular) by high levels of U in most samples (up to 17%). Attempts are currently being made to overcome these interferences by developing an AAS major-element method. The analytical work has been possible through the assistance of B.I. Cruikshank, N. Davis, J.G. Pyke, and T.I. Slezak.

Detailed petrology is planned. From earlier work on the Alligator Rivers deposits, it has been recognised that the dominant feature of the mineralogy is the ubiquitous occurrence of a number of varieties of chlorite. Where primary uranium mineralisation occurs, it is intimately associated with chlorite, and it is proposed to continue investigations into this association through detailed electron-microprobe analysis.

The small number of samples, the sparcity of coexisting sulphides, and the absence of carbonates in association with graphitic material, indicate that there is little scope for stable-isotope studies. However, subject to the results of petrographic work, some limited stable isotope works may be feasible and appropriate (in conjunction with T.H. Donnelly, CSIRO).

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*In URANIUM IN THE PINE CREEK GEOSYNCLINE. IAEA, Vienna.

GEOCHEMISTRY AND PETROLOGY OF LOWER PROTEROZOIC METASEDIMENTS IN THE PINE CREEK GEOSYNCLINE by G.R. Ewers

The main objectives of this project are:

a) to establish a data base for the different lithologies and rock units in the Lower Proterozoic metasedimentary sequence of the Pine Creek Geosyncline. It may be possible to fingerprint certain units on the basis of their chemistry, and establish trends for given rock types across the geosyncline as a function of depositional environment, time of deposition, etc.

b) to assess the effects of low to medium-grade regional metamorphism and contact metamorphism on the geochemistry of the sediments. The lower Proterozoic metasediments of the Pine Creek Geosyncline are of major significance in that they form the bulk of the rocks within the geosyncline and host virtually all the economic deposits in the region (including the major uranium deposits of the Alligator Rivers uranium field)

Approximately 350 samples have been collected from shallow stratigraphic and deep diamond drillholes across the Pine Creek Geosyncline. The drilling was carried out by BMR throughout the 1970s, and has provided material from below the weathering zone and removed from areas of known mineralisation.

Whole-rock analysis (major elements plus Ba, B, F, Ce, Co, Be, Cu, Ga, Li, La, Mo, Ni, Pb, Br, Sn, Sr, Th, U, V, W, Y, Zn, Zr, CO_2, $H_2O\pm$) is nearing completion. The analytical work has been possible through the assistance of B.I. Cruikshank, K.H. Ellingsen, C.R. Madden, J.G. Pyke, and T.I. Slezak. Petrographic work is also nearing completion.

When completed, the data will be processed using the Hewlett Packard 9825 system and its peripherals (i.e., plotter and printer).

Whether the results are to be published as a series of short publications or a single large report is yet to be resolved. Reporting should commence in late 1981 and continue into the first half of 1982.

ANALYTICAL LABORATORY by B.I. Cruikshank

Staff: B.I. Cruikshank, G.R. Ewers, C.R. Madden (to 4 July), J.G. Pyke, T.I. Slezak

During the year, 1980 samples were analysed for a total of 35,400 element determinations.

There have been some problems with staffing as only two of the laboratory's five technical positions are now occupied, although this situation should be alleviated in the near future by recruitment to two of the vacant positions.

Laboratory projects receiving major support included:-

1) the petrochemical study of the PINE CREEK metasediments (333 samples)
2) the ARALUEN geochemical survey (323 samples)
3) the Ranger I soil geochemistry survey (263 samples)
4) the PINE CREEK geochemical orientation survey (173 samples)

About 430 samples came from sources outside Metalliferous Laboratories.

X-ray fluorescence spectrometry

Five-hundred-and-twenty-three (523) silicate samples, mostly from the Pine Creek metasediment study and the alkaline-ultramafic rock project, were analysed on the major-element program. For the first time, this program was run on the laboratory's PW1450 spectrometer.

Trace elements were determined on 1680 samples (17 100 element determinations).

Atomic absorption spectrophotometry

Trace elements were determined on 1850 samples (11 600 element determinations).

Chemical methods

The laboratory's CO_2/H_2O line was installed this year and 424 samples, most being from the Pine Creek metasediments study and the alkaline-ultramafic rock project, were analysed for CO_2 and H_2O+; a further 31 samples were analysed for H_2O+ only. Two-hundred-and-forty-seven (247) samples were analysed for FeO.

GEOCHRONOLOGICAL LABORATORY

INTRODUCTION by R.W. Page

The Geochronology Group has continued to employ U-Pb and Rb-Sr dating techniques on several projects in the Northern Territory, Queensland, Antarctica, Tasmania, New South Wales, and South Australia. An extra staff member (Mr D. Guy) joined the sample preparation area. During the year 20 complete zircon mineral separations, 12 other mineral separations, and about 150 total-rock crushings were completed. A considerable amount of sample preparation time was lost through repairs to the crushing equipment, sick leave, and long-service leave.

There was also a large proportion of down-time on the mass spectrometers owing to fouling and misalignment of the source assembly.

The sharing of Rb-Sr and U-Pb isotope laboratory facilities with the Research School of Earth Sciences, ANU, is a continuing beneficial arrangement for both organisations. This co-operation has been extended recently by the joint purchase of a new automated mass spectrometer, and by BMR's contribution to computer-software development for the ANU-built ion microprobe facility.

Comparisons with X-ray fluorescence spectrometry revealed that anomalous Rb and Sr concentrations were being given by isotopic dilution analysis in some rocks, particularly those with high Ca contents. Modifications were made to the acid dissolution procedure which have eliminated this problem for all rock compositions.

The production of ultra-clean reagents continued and processing blanks of about 0.2×10^{-9} g for Pb, 0.4×10^{-9} g for Rb, and 5×10^{-9} g for Sr were maintained. A new Pb-206 isotopic tracer was also made and calibrated during the year; its prime use is for the analysis of Pb concentrations in monazites.

Page continued to co-supervise (with Dr W. Compson) the U-Pb zircon work of two visiting Chinese geochronologists, Mr Liu Dun-yi and Mr Chang Zi-chau. These workers returned to China in September.

WESTERN TASMANIA by L.P. Black.

Previous Rb-Sr work produced deformational rather then stratigraphic ages for the Mount Read Volcanics. Consequently emphasis has changed to the U-Pb zircon technique for the dating of these rocks. An age of about 511 m.y. has been obtained for the Darwin Granite which intrudes the central volcanic belt. Zircons from a central belt lava and Tyndall Group ignimbrite show some inherited Pb, but have a maximum age of 540 m.y. assuming similar Pb-loss trajectories for rocks with common post-crystallisation histories. A joint paper was presented by C.J. Adams at the Fourth Australian Geological Convention in Hobart.

ARUNTA INLIER by L.P. Black

Manuscripts on the Stuart Dyke Swarm and the Jervois Range area have been completed and accepted for publication. In the former an internal mineral isochron age of 897 $\pm$ 9 m.y. was obtained for dolerite dykes which intrude the Arunta Inlier. These dykes are unconformably overlain by the Heavitree Quartzite, basal formation of the Amadeus Basin sequence, for which they provide an older age limit. This limit is consistent with all isotopic data except previously determined glauconite ages from the Vaughan Springs Quartzite - a correlative, in the Ngalia Basin, of the Heavitree Quartzite. It seems probable that the glauconite grains were either at least partly reworked from older rocks, or have grown around small grains of detrital mica and inherited the isotopic characteristics of that mica. An age of 990 $\pm$ 13 m.y. for granite in the Harry Creek Deformed Zone should also represent a maximum age for the sediments preserved in the Amadeus Basin for they are nowhere seen to be intruded by granite.

The oldest event recorded by the Rb-Sr system in the Jervois Range area, in the east of the Arunta Inlier, is the intrusion of the post-tectonic Jinka and Jervois Granites at about 1750 m.y. This becomes a minimum age estimate for the main metamorphism in the country rocks. The metamorphism is presumably the same as the earliest detected metamorphism in the Arunta Block itself which is dated at about 1800 m.y. A pink foliated alaskitic granite from the Jervois area was probably intruded at 1459 $\pm$ 10 m.y. Two pegmatites were emplaced during a third event, of intermediate age, about 1642 $\pm$ 26 m.y. ages. Mineral ages are generally younger than total-rock ages, but no values less than that of the alaskitic granites were found. Thus, the Alice Springs Orogeny, which has extensively reset large areas to the west did not affect the Jervois area. In this and other geochronological comparisons, the Jervois area is more similar to the rocks of the Tennant Creek Block than to those of the western part of the Arunta Block.

ALKALINE ULTRAMAFIC PROJECT by L.P. Black

Concordant $^{238}U/^{206}Pb$, $^{235}U/^{207}Pb$, and $^{207}Pb/^{206}Pb$ ages of about 172 m.y. were obtained for zircon from kimberlitic rock in South Australia. This age is in agreement with previous ages determined by K-Ar and Rb-Sr methods on phlogopite separates.

COBAR SUPERGROUP by L.P. Black

A project is underway, in conjunction with R.A. Glen of the Geological Survey of New South Wales, to attempt to date the main deformation in the Cobar Supergroup. Because of problems with isotope dilution procedures referred to in the introduction of the Geochronological Laboratory report, the samples were analysed several times each. A total of 33 complete analyses for Rb and Sr were made. Analyses are now complete and the data are being assessed. At this stage, however, it appears that the deformation was not sufficiently intense to produce Sr re-equilibration.

ENDERBY LAND, ANTARCTICA by L.P. Black

Black spent a further 3 months on sample collection from the Napier and Rayner Complexes. Geochronological samples were taken from 17 sites, and a geochemical sample from an additional locality. More emphasis was placed on collecting paragneisses than in the previous season, in an attempt to derive some precise Rb-Sr isochron ages. D_1 and D_2 fabrics were sampled in the Napier Complex, as well as granites and mylonitic rocks. Further sampling should produce good geochronological control in the Field Islands. A pyroxenitic anorthosite was sampled from the Nye Mountains.

During May, P.R. James presented a joint paper on the structural evolution and geochronology of Enderby Land at the Second International Archaean Symposium in Perth.

Isotopic dating is difficult in this region of superposed events because high metamorphic grade and generally dry conditions have not allowed the regular production of overprinted schistosity or crenulation cleavage. Consequently, the interpretation of the geochronology is highly dependent on microfabric analysis. The main task is to ascertain to which, if any, of the events a derived age relates. Partial resetting, in which an age has no direct reality, but lies between those of two events, is a major problem.

Zircons from Mount Hardy plot near the $^{206}Pb/^{238}U$ - $^{207}U/^{235}U$ concordia at about 2480 m.y. Those from Mount Sones form a linear array stretching from that value towards about 3000 m.y. Tholeiite dykes cut the Napier Complex, but are nowhere seen to be folded. The oldest of these dykes yield Rb-Sr total rock ages of 2420 $\pm$ 230 m.y. (metatholeiites) and 2350 $\pm$ 48 m.y. (high-Mg tholeiites). 2480 m.y. is thus thought to represent the last structural/ deformation event (D_3) within the Napier Complex. The 3000 m.y. event is ascribed to D_2 but, because of similar styles of D_1 and D_2 folding, is also thought to approximate the age of D_1.

A distinct group of quartz tholeiite dykes yield an age of 1190 $\pm$ 200 m.y. from a model I isochron. This implies that at that time an extensive source region of uniform $^{87}Sr/^{86}Sr$ underlay at least 15 000 km^2 of Endergy Land. The $^{87}Sr/^{86}Sr$ isotopic composition of that source is, however, almost 0.001 higher than that predicted for the bulk-earth model from the ^{143}Nd - ^{87}Sr anticorrelation found in oceanic basalts. Conversely, the initial $^{87}Sr/^{86}Sr$ ratio of the high-Mg suite and the metatholeiites is precisely that predicted from the model.

Currently Rb-Sr and zircon work is being concentrated on the Fyfe Hills and Field Island areas. No evidence of pre-3000 m.y. ages is apparent. However, both areas record evidence of a pronounced 2500 m.y. event.

In early October Black visited P.R. James (Adelaide University) and S. Harley (University of Tasmania), coworkers on the Enderby Land project. James is providing structural control for the interpretation of isotopic ages, and Harley is using geothermometry and geobarometry method to estimate the conditions under which isotopic equilibration occurred.

<u>McARTHUR BASIN</u> by R.W. Page

The objective of this project has been to find the depositional age of the McArthur Group from the U-Pb dating of zircons from thin, potassium-rich tuff horizons. These rocks are interbedded with mineralised sediments, and the sample used was from a unit termed the Lower Dolomitic Shales, immediately below the HYC orebody. The tuffs, although probably water-laid, are basically of igneous derivation, and this is consistent with the euhedral morphology of the zircon grains. Only very small amounts of zircon occur in such tuffs, and, in the McArthur Basin samples, 8 size/magnetic fractions were extracted, most weighing 0.0002 g or less and providing about 50 x 10^{-9} g of Pb for analysis.

These zircons have minimum $^{207}Pb/^{206}Pb$ ages of around 1650 m.y., and internally consistent isotopic relations in the system $^{206}Pb/^{238}U$ - $^{207}Pb/^{235}U$ give an apparent U-Pb age of crystallisation of 1685 ± 25 m.y. This result is consistent with existing stratigraphic and geochronological control which had previously bracketed the McArthur Group in the interval 1800 to 1360 m.y. Thus, the 1685 m.y. age is a good estimate for the age of volcanism, and is the best available age for the McArthur Group itself. The result is statistically indistinguishable from the U-Pb zircon age of the Mount Isa Group tuff marker bed, and provides excellent evidence for the inter-regional correlation of the two groups, as has been suggested previously on broad stratigraphic grounds.

MOUNT ISA INLIER by R.W. Page

This study is directed at elucidating the chronology of several suites of Proterozoic volcanic and intrusive rocks in the Mount Isa Inlier. It is providing fundamental stratigraphic guidance in some parts of the sequence where field relations are open to divergent interpretations. The study primarily employs the U-Pb zircon technique, and its use is enabling the age of geological events to be determined, and is providing answers to such questions as: What is the relation between the various igneous and metamorphic events? Are the igneous events periodic or continuous? What do the isotopic tracers indicate about processes of granite formation and the nature of the source rocks?

Ages of some volcanic sequences

Good progress was made in determining stratigraphically meaningful ages for several important felsic volcanic markers in the sequence. A notable finding is that the oldest (1870 m.y.) felsic volcanic sequences north of Mary Kathleen (Leichhardt Metamorphics) have close equivalents about 140 km south of Mary Kathleen. The latter, formerly termed Standish Volcanics, have similar dacitic to rhyodacitic lithologies to the Leichhardt Metamorphics, and the combined zircon data from the two widely spaced samples provide U-Pb zircon ages of about 1870 m.y. These are igneous crystallisation ages, and represent the oldest crustal development yet recognised in the Mount Isa Inlier.

An important, and as yet unresolved, question is the age of the widespread calc-silicate rocks termed Corella Formation. This unit is mapped throughout the eastern part of the Mount Isa Inlier. Geological arguments about the relative stratigraphic position of the Corella Formation cover a wide spectrum of possibilities. In the Duck Creek Anticline, a U-Pb zircon age of about 1760 m.y. was obtained for a felsic volcanic sequence which underlies the Corella Formation in this structure. This is only slightly younger than similar 1775 m.y. volcanics of the Argylla Formation previously found to be north of Mary Kathleen, and it is therefore regarded as a maximum age for the Corella Formation. The Burstall Granite intrudes the Corella Formation and has a U-Pb zircon age of 1740 m.y. Thus, the depositional age for the Corella Formation in this area is constrained to the interval 1740 to 1760 m.y.

Age results now in hand on two other rhyolites associated with the Corella Formation, suggest that the geology of these rocks is far more complex than previously considered. One of the rhyolites (in the Tommy Creek area) is interbedded with fragmental volcanics, shales and calcareous rocks. Its zircon morphology and the linearity of the U-Pb isotopic data suggest a primary igneous crystallisation age of around 1615 m.y. Nearby subvolcanic microgranites had previously given a statistically indistinguishable age of 1607 m.y. The pooled age of around 1610 m.y. indicates that this sequence is one of the youngest in the Mount Isa Inlier, and it implies that an as yet unrecognised important structural break is present between this 'Corella' sequence and the previously described ca. 1750 m.y. 'Corella' sequence.

A further complication of this issue arises from U-Pb zircon results on another rhyolite associated with the Corella Formation in the southeastern part of the inlier. This unit gives an igneous crystallisation age of ca. 1700 m.y. This felsic unit is considered to be an extrusive, but this has not been definitely established in the field, and the age can only be thought of as a minimum for the Corella Formation, as would be the case if it is actually a subvolcanic intrusive.

In summary, geochronological constraints relevant to the so-called Corella Formation, indicate two distinctly different ages of formation, one between 1740 and 1760 m.y., and the other ca. 1610 m.y. This implies that the rocks are composed of two or more formational units, and that an important structural break exists between them.

Ages of plutonic bodies

Most of this program was devoted to the complex of granitic rocks termed the Sybella and Big Toby Granites immediately west of Mount Isa. It was undertaken to better define the intrusive history, and the relations between the granites and nearby volcanic and sedimentary units, including the Carters Bore Rhyolite (1680 m.y.), and the Mount Isa Group (1670 m.y.) and its equivalents.

The U-Pb zircon age of the Big Toby Granite is 1800 m.y.; this indicates that the body is part of the basement to the Mount Isa Group sequence. As expected, the zircon result is about 90 m.y. older than the previously reported Rb-Sr total-rock age. The U-Pb work on lithologically distinct phases of the Sybella Granite so far indicates that these bodies are coeval, and all were emplaced at about the same time but 130 million years after the nearby Big Toby Granite. The northwestern porphyritic phase and the southern foliated gneissic phase of the Sybella Granite have nearly identical zircon ages of close to 1670 m.y., implying that the latter phase (comprising most of the batholith) is merely a deeper-level zone within the igneous mass. The data are so consistent and linear, that only a single generation of zircon is present, suggesting that the well-developed fabric of the southern phases was imposed during emplacement. Once again, these new U-Pb zircon results are about 5 to 8 percent older than previously reported Rb-Sr total-rock results, which have been affected by alkali mobility during low-temperature localised hydrothermal alteration processes.

This study has shown up an important and unexpected temporal connection between the Sybella plutonic development and nearby felsic tuffs interbedded with the mineralised Mount Isa Group. The Sybella Granite ages (ca. 1670 m.y.) are the same as the age of the Mount Isa Group (1670 $\pm$ 17 m.y.), which suggests that the Sybella Granite could have been a heat source during the deposition of the Mount Isa Group.

Further work was carried out on the Lunch Creek Gabbro near the Burstall Granite, the oldest component of which, as mentioned earlier, has a U-Pb zircon age of about 1740 m.y. A gabbroic pegmatoid from the Gabbro yielded stubby, shapeless zircons, in complete contrast to those from the Burstall Granite. Previous Rb-Sr measurements on the Gabbro suggested that it was relatively young (1490 m.y.), but this could not be rationalised with the fact that the granitic veins appear to cut the Gabbro. New U-Pb zircon measurements on the Gabbro are very concordant, and indicate that it is virtually the same age (1740 m.y.) as the Burstall Granite, thus explaining the apparent anomalous field interpretations.

PINE CREEK GEOSYNCLINE by R.W. Page

Litchfield Complex

A reconnaissance Rb-Sr total-rock study is being undertaken on granitic rocks and gneisses from widely spaced areas of the Litchfield Complex, southwest of Darwin. The aim is to establish the age of the Litchfield Complex and/or to establish any genetic link, from Sr isotopic evidence, with the late Archaean Rum Jungle Complex. This information would be of some use in mineral exploration, as some models of uranium petrogenesis in the region call on the existence of an Archaean basement as a prerequisite for uranium mineralisation in Lower Proterozoic metasediments. The Rb-Sr results so far suggest that the Litchfield Complex is Proterozoic in age (ca. 1800 m.y.). If this is substantiated, the Complex should no longer be regarded as equivalent to the Rum Jungle Complex.

Dolerite emplacement

Despite a considerable amount of effort to determine the age of Early Proterozoic sedimentation in the Pine Creek Geosyncline in the East Alligator River region (Page & others, 1980)*, the rocks were not amenable to direct dating, and always yielded ages that are too young, reflecting or partly reflecting the 1800 m.y. metamorphic overprint. With the data then available, Page & others (1980) concluded that a model Rb-Sr age of 2000 to 2200 m.y. was the best estimate that could be made for the age of Lower Proterozoic sedimentation.

A firmer hold on the age of these Proterozoic sequences has now been obtained by means of Rb-Sr total-rock and mineral work. The Rb-Sr work has been directed at outcrops of dolerite (Zamu Dolerite) in the South Alligator River area. These are folded concordantly with the Lower Proterozoic sequence, and are considered by some workers as being conformable within the sequence. The latter relationship cannot be proved, however, and the age of the Zamu Dolerite must therefore be considered a minimum age for the Lower Proterozoic sequence. The total-rock data for most of the dolerites are aligned about a 1940 m.y. isochron, the initial $^{87}Sr/^{86}Sr$ being 0.7065. This provides the best available (minimum) estimate for the age of Lower Proterozoic sedimentation and it is entirely consistent with existing age constraints. Work is in progress to

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*In URANIUM IN THE PINE CREEK GEOSYNCLINE. IAEA, Vienna substantiate this result by U-Pb zircon dating of tuffs and lavas interbedded elsewhere in the sequence.

An unexpected bonus from this dolerite Rb-Sr analytical program is the recognition of a second dolerite suite in the same area, but some 250 million years younger. Rocks of this suite also intrude the Lower Proterozoic meta-sediments, and are characterised by partly altered olivine and fresh red-brown biotite. Such dolerites form the bulk of the 1690 m.y. Oenpelli Dolerite intrusives to the north in Arnhem Land. The relative lack of alteration is evidently due to the fact that these bodies were emplaced after 1800 m.y. regional metamorphism, and this is again shown to be so by the newly acquired Rb-Sr mineral and total-rock data which are well aligned (apatite, clinopyroxene, plagioclase, biotite, and total rocks) and indicate an age of emplacement of 1685 m.y. This is virtually identical to the Oenpelli Dolerite age reported by Page & others (1980), so it is now clear that rocks of this same vast mafic intrusive suite can now be recognised much farther south than previously thought.

BEACH-SAND HEAVY-MINERAL PROVENANCE PROJECT by R.W. Page

Heavy minerals such as zircon and monazite concentrated in beach-sand mineral deposits, provide a sample of very large masses of the igneous rocks from which they were derived.

This pilot study of some eastern Australian and western Australian zircons and monazites from beach-sand concentrates is designed to see if there are any regularities to the pattern of U-Pb ages. This will provide a gross guide to the provenance of the material, and hence help to elucidate when and how such deposits were formed.

Zircon and monazite concentrates from Southport and Stradbroke Island (east coast), and Bunbury and Busselton (west coast) are in hand, and pure monazite has been beneficiated from three of the concentrates. A single monazite analysis from the Southport sample indicates a $^{207}Pb/^{206}Pb$ age of about 1000 m.y. This is a minimum age for the bulk sample, but its geological significance cannot be assessed until further measurements are made.

MISCELLANEOUS ACTIVITIES

PRECAMBRIAN REGIONAL GEOLOGY by K.A. Plumb

During the year the paper by Plumb, Derrick & Wilson, on 'Precambrian geology of the McArthur River-Mount Isa region, northern Australia' was published in 'Geology and Geophysics of Northeastern Australia' by the Geological Society of Australia.

The review paper - 'The Proterozoic of northern Australia' by Plumb, Derrick, Needham, & Shaw - in the Elsevier book, 'Precambrian of the Southern Hemisphere', and papers by Plumb on the late Proterozoic tillites of the Kimberley-Victoria region and the Duchess area, for IGCP Project 38, are still in press. Proofs were corrected during the past year.

INTERNATIONAL CONFERENCES AND OVERSEAS VISITS

SYMPOSIUM ON QINGHAI-XIZANG (TIBET) PLATEAU by K.A. Plumb

Academia Sinica invited Plumb to attend the multidisciplinary Symposium on Qinghai-Xinzang (Tibet) Plateau in Peking, from 25 May - 1 June 1980, followed by a 950 km field excursion across southern Tibet from June 2-14. The Tibet Plateau, with an area of 2.4 million km^2 and average elevation of 4500-5000 m, is the largest single elevated block in the world. It lies in a key position in the Alpine-Himalayan Chain, and the mechanism of its uplift is fundamental to geotectonic theory. The height, size, and rapid rise of the plateau make it of great importance to many other sciences. Foreign access to Tibet has been restricted for centuries. This symposium was important because it represented:

1) The first major international scientific symposium within the People's Republic of China;
2) The first time that a wealth of new scientific data from 15 years of Chinese research in Tibet was released internationally;
3) A unique attempt to address so many scientific disciplines to one problem.

Seventy-nine non-Chinese scientists from 18 countries and 205 Chinese scientists attended the meeting. Two-hundred-and-fifty-nine papers covered the fields of geology, geophysics, geochemistry, stratigraphy and palaeontology, zoology, botany, physiology, geomorphology, geography, and meteorology; the majority (150) were in earth sciences. All papers are being published in a 2000-page volume by Academia Sinica. Plumb has fully reported the meeting, field excursion, and his conclusions in Record 1980/65.

Plumb's interest is in the possible application or otherwise of the Himalaya-Tibet model to Proterozoic mobile belts. His paper - Precambrian Tectonics in Australia, viewed from the Himalayas and the Qinghai-Xizang Plateau" - reviewed three Australian mobile belts, for their comparison with the Himalayas and Tibet Plateau.

The Tibet Plateau was shown to have formed by the successive accretion of continental and/or island arc fragments between the late Palaeozoic and Cainozoic. By far the majority of the rocks now seen are of continental origin. The principal accretionary block is the Indian Subcontinent, which collided with Eurasia in the Early Tertiary and created the Himalayas. Features seen in the field amply demonstrated the history of this event - opening of the Tethys ocean in Triassic; convergence and subduction in Late Cretaceous-Eocene; collision in late Eocene-early Oligocene; underthrusting and metamorphism of the Himalayas in mid-Late Tertiary. The great uplift of the Plateau is a very young event - 4000 m of uplift in only 1 million years since the end of the Pliocene. The uplift is the result of isostatic adjustment to crustal thickening, which took place due to crustal shortening during intracontinental convergence.

Many similarities were seen between the Himalayas-Tibet Plateau and the enigmatic Proterozoic mobile belts. Plate tectonic models, particularly those involving Tibetan-style collision phenomena, may well provide an adequate mechanism of formation of the apparently ensialic Proterozoic mobile belts. The popularly accepted ensialic intracontinental models of Proterozoic mobile belts need to be critically reappraised in terms of the new data originating from the Himalayas and Tibet Plateau.

VISIT TO IGC, PARIS, AND GEOLOGICAL SURVEY OF CANADA by G.M. Derrick

G.M. Derrick attended the IGC in Paris from 7-17 July, 1980, as an official BMR delegate. He attended numerous sessions on Precambrian geology, tectonics, petrography, metallogenesis, geochemistry, and remote sensing, and represented BMR and other Australian interests at subcommission meetings for the Commission for the Geological Map of the World (CGMW), in the fields of metamorphic and environmental geological maps.

A paper was presented describing the 'Anatomy of a Proterozoic Rift' at Mount Isa. Throughout the Precambrian and some other sessions, there was considerable emphasis on the role and nature of tensional tectonics and related sedimentation and magmatism, and relations between mineral deposits and their palaeogeographic setting. The Roxby Downs deposit engendered much interest throughout the conference. Derrick also attended a weekend excursion to view platform exposures of the Armorican Massif near Nantes, southwest of Paris, where Precambrian? and lower Palaeozoic volcanic, sedimentary, and granitic sequences have been subjected to metamorphism and anatexis.

At the Geological Survey of Canada, Derrick discussed:

(1) aspects of the Economic Geology Division of GSC, specifically the operations and techniques of the Mineral Deposits Geology and Uranium Resource Evaluation groups, with a view to implementing of similar groups in BMR. The Cu-Mo, Ag-Pb-Zn, and U groups were examined (commodity specialists), as well as the role of the regional metallogenists, who combine the work of the commodity groups with more detailed knowledge of certain broad regions e.g. Yukon, Great Bear/Great Slave, Superior/ Churchill provinces;

(2) Precambrian geology of Canada, with the Precambrian division of GSC, and exchanged data on Mount Isa geology. He also discussed Precambrian geology with Dr A. Baer and Dr J.A. Donaldson from the University of Ottawa and Carleton University respectively.

In Toronto at the Royal Ontario Museum, Dr T. Krogh discussed problems of U-Pb zircon geochronology, and explained his latest research into the abrasion of zircon grains to further refine the U-Pb ages. Some recent age data from this laboratory of 2958.6 ± 1.7 m.y. reflect the increasing precision of the U-Pb zircon method.

A more detailed report on this overseas trip is being prepared as a BMR Record.

GEOLOGICAL SERVICES SECTION

Head: E.K. Carter

ENGINEERING GEOLOGY AND HYDROGEOLOGY

STAFF: E.G. Wilson, G. Jacobson, G.A.M. Henderson, J.R. Kellett, W.R. Evans, P.H. Vanden Broek (resigned 2 May 1980), G. Sparksman, B. Jones (until October), A.W. Schuett, R. McPake.

HYDROGEOLOGICAL STUDIES IN THE A.C.T. AND ENVIRONS

DEFINITION AND MAPPING OF HYDROGEOLOGICAL PARAMETERS by W.R. Evans and J.R. Kellett

All data on the 520 bores currently listed in the A.C.T. and adjoining area are being re-evaluated for incorporation into a computerised data base. Additional information is added to the data base as it becomes available from BMR sources, NSW Water Resources Commission, and from private drilling contractors.

Areas of detailed study have been defined to enable the geologic, geomorphic, and water quality processes in the aquifers to be delineated, and some equipment has been developed for aquifer testing. Areas selected include the Ororral valley (granite), the southern Tuggeranong valley (Silurian volcanics), and the upper Yass River valley (Ordovician metasediments) as representative geologic provinces; the North Canberra Plain (deep weathering profile) as a representative geomorphic province; and the Majura valley (Ainslie Volcanics) and the Wallaroo-Bedulluck area (Hawkins and Laidlaw Volcanics) as representative water quality provinces. Studies within these areas have commenced. Pumping and observation bores for long-term aquifer testing have been drilled (by BMR Drilling Section) and logged in the upper Yass River, southern Tuggeranong, and Ororral valleys. Similar work is programmed for the remaining provinces.

The current studies will facilitate the characterisation of the hydrogeological parameters of the various geological, geomorphological and hydrogeological provinces in and around the A.C.T. The results will be present in a hydrogeological map of the A.C.T. at 1:100 000 scale.

UPPER YASS CATCHMENT STUDY, NSW by W.R. Evans

The group continues, jointly with CSIRO, a study of the upper Yass River valley catchment which has been designated a representative basin by the Australian Water Resources Council. BMR work is aimed at defining the subsurface components of the basin hydrology; it commenced in 1978. The drilling program for identification of aquifer systems was completed in 1979, and data on groundwater has been steadily building up for application to basin analysis; however, the drying out of the alluvial aquifer systems during the present drought will cause some delay in the acquisition of comprehensive data.

The stratigraphy of the surficial material has been delineated: the basin is blanketed by two widespread units, the Kowen Pedoderm and the Murrayong Pedoderm (see Fig. G1).

The Kowen Pedoderm is mainly a braided stream deposit, between 1 and 5 m thick. The basal clastic bed-load facies forms the major surficial aquifer in the catchment. Pedogenesis has modified the unit to form a yellow podzol that has subsequently been truncated.

The Murrayong Pedoderm is poorly developed, and rarely exceeds 1 metre in thickness; it also has a clastic stream deposit facies, acting as an aquifer. Pedogenesis has produced a yellow-earth-profile with a highly bleached A horizon. Murrayong pedogenesis commonly extends into the Kowen cycle.

Other units have been mapped from isolated remnants and drill hole information, but have not, as yet, been fitted into the soil-stratigraphic framework.

CAMP WATER SUPPLY BORE, TIDBINBILLA, A.C.T. by J.R. Kellett

A 48-hour step drawdown test was done on a domestic water supply bore, in fractured adamellite at the Birringai National Fitness Camp, to ascertain safe long-term pumping rates.

Nine pumping steps of unequal duration were employed at rates ranging from 16.7 m^3/day to 51.6 m^3/day and instantaneous changes in drawdown were recorded with a pressure transducer. Corrected drawdowns for each pumping rate were calculated by linear regression. Variable delayed yield and ephemeral recharge were experienced when open fracture zones in the adamellite were intersected as the core of depression spread during the longest time steps. Once the fracture zones had been drained, the time-drawdown curve reverted to the original gradient; the transient effects were therefore omitted from the regression analysis.

Predicted drawdowns as a function of pumping rate and time were obtained by regression of the pressure differential and drawdown points for each step. Bore development during the first few steps of the pump test was indicated by temporary increases in turbidity of discharged water with the sudden

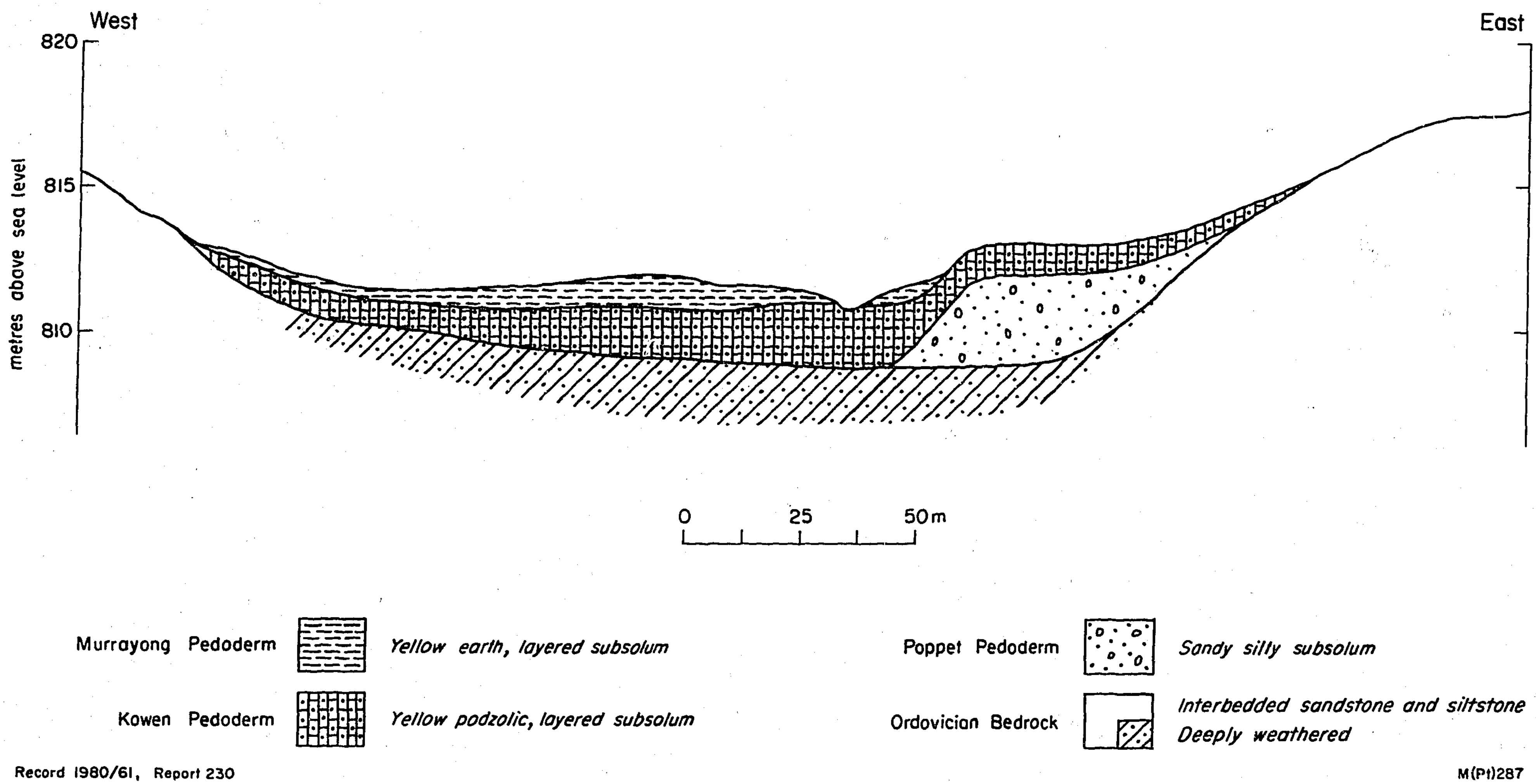


Fig. G1 Schematic cross-section showing relationship between pedoderms, upper Yass River valley.

application of higher pumping rates and by initial negative values of the well-loss constant.

The critical Q-value was determined to be 45 m^3/day, after which drawdown increases exponentially in the turbulent flow regimen. This is attributable to the impedance to inflow to the well by the casing slots, which appear to have an effective porosity significantly lower than the open joints of the aquifer.

An intermittent pumping rate of 40 m^3/day has been selected by the camp's authorities; on the basis of the predictive equations derived from the test, the maximum drawdown that can be expected at the end of 1 year ranges from 9.4 m if pumping is for 8 hours per day to 13 m if this rate (40 m^3/day) is maintained for 24 hours per day, assuming steady recharge to the aquifer.

HYDROLOGY OF LAKES GEORGE AND WINDERMERE by G. Jacobson

Monthly monitoring of Lake George, NSW, water-levels continued. The lake was at its lowest spring level for several years in September 1980, when its maximum depth was 1.50 m and salinity about 7000 parts per million. Revision of the lake water-balance model was undertaken.

In the Federal Territory of Jervis Bay, monitoring of water-levels continued in Lake Windermere in a network of 17 observation bores, continued. The data will be used to construct a lake water-balance model, which will take into account the loss of water from the lake by groundwater seepage. The lake water-level is falling, after high levels in the mid-1970s.

POLLUTION OF GROUNDWATER by G. Jacobson

Surveillance of six sites in the Australian Capital Territory continued in collaboration with the Department of the Capital Territory.

Pollution of groundwater by petrol leaked or spilled from underground storage installations has occurred in recent years at two locations in Canberra. A remedial pumping system has been installed at one of these sites - the Center Cinema in Canberra City - and some petrol has been recovered from the ground. Monitoring of this system continued throughout the year. At the second location - the NRMA Building in Braddon - monitoring of the petrol pollution plume was also continued throughout the year.

Monitoring continued at two operating sanitary landfill sites, one disused landfill site, and one site affected by industrial pollution. A paper on geological factors in the development of landfill sites was prepared by Jacobson and W.R. Evans for the BMR Journal, and the other investigations were reported in the BMR Record series.

GROUNDWATER RESOURCES INVESTIGATIONS

Advice concerning the siting of bores and development of well fields was given, as follows:

Animal park, eastern A.C.T. (National Capital Development Commission)
Majura valley (lease holder)
Canberra Racecourse
Belconnen Golf Club
Googong Dam picnic ground (Department of Housing & Construction)
Tharwa village (National Capital Development Commission)

HYDROGEOLOGICAL STUDIES ELSEWHERE

LACHLAN VALLEY SALINITY, NSW by W.R. Evans and J.R. Kellett

The group is undertaking, jointly with CSIRO, a study of the occurrence of high-salinity groundwater in the Lachlan Valley, with the object of determining its origin.

Two holes were drilled in the Begargo Creek catchment southwest of Lake Cargelligo (NSW), during March 1980. One hole, LC1, was drilled to 100 m through fractured Silurian quartzose sediments and was cased to monitor the fractured-rock aquifer only. The second hole, LC2, which ended at 22.5 m at the top of the bedrock weathering profile, was screened in surficial sand aquifers.

A pump test on LC1 was conducted in June 1980 and preliminary results indicate a transmissivity of about 0.5 m^2/day. Conductivity measurements during pumping indicate an electrical conductivity of 33 x 10^3 µS/cm; and chemical analyses of samples show that the water is high in Na (43.6% of total ions), C1 (40.8%), SO_4 (8.4%), and Mg (5.4%).

Eighteen samples down the weathering profile have been analysed for clay minerals by X-ray diffraction techniques; the results show classical degradation of 2 ml muscovite to illite on weathering.

Further drilling and testing of the surficial cover and the fractured rock is proposed for 1981.

ALLIGATOR RIVERS HYDROGEOLOGY, NT by J.R. Kellett

BMR was requested by the Office of the Supervising Scientist (OSS) to investigate the hydrodynamics and hydrogeochemistry of the surficial aquifer of the Magela and Cooper Creek catchments. Northern Territory authorities were similarly requested to determine the hydrogeology of the fractured bedrock. A transport model is to be developed for groundwater management in the uranium mining areas of the Alligator Rivers region.

A BMR field party was based at Jabiru from July to November 1979. Monitoring bores were installed at Nabarlek and in the southern Magela valley and an extensive program of infiltration testing was carried out.

A progress report was issued in January 1980 which contained a summary of completed work and a proposed program for 1980 to complete drilling and to establish regular water-quality sampling. Because of budgetary constraints the OSS was not able to provide funds to BMR to carry out the 1980 program.

A consultant was engaged by OSS to review the total Commonwealth-Northern Territory hydrogeological program in the Alligator Rivers area with a view to cutting expenditure. The consultant concluded that the surficial aquifers are the most environmentally critical element of the groundwater regime, and recommended that the program should be accelerated along the lines proposed by BMR to accumulate as much baseline data as possible.

At meetings in Darwin in July 1980 between BMR and Northern Territory authorities, it was agreed that hydrogeological work on deep basement aquifers should be diminished, and that most future expenditure on hydrogeological research should be directed towards the surficial aquifers. In order to eliminate direct Commonwealth funding, it was also agreed that the work should be taken over by Northern Territory Water Division with specialist assistance from the Geological Survey of the Northern Territory (GSNT).

BMR participation in this project has been discontinued except for the drilling of four stratigraphic drillholes in the northern Magela floodplain, the results of which are not yet to hand. The holes are being logged by GSNT.

HYDROGEOLOGY OF NIUE ISLAND - A FOREIGN AID PROJECT by G. Jacobson

An investigation of the groundwater resources of Niue Island, South Pacific Ocean, was undertaken in 1979 on behalf of the Australian Development Assistance Bureau. Report writing continued into 1980 and a paper on the hydrogeology of Niue was prepared by Jacobson and P.J. Hill for the BMR Journal. The investigation has assured Niue of a freshwater supply sufficient for its foreseeable requirement.

As a result of the encouraging results of the investigation, given in the 1979 Geological Branch Summary of Activities, follow-up work is being undertaken under the Australian bilaterial aid program. A CSIRO irrigation expert has visited Niue to examine the possibility of developing commercial agriculture there, and trial irrigation plots have been established. BMR officers have been engaged in preparing specifications and evaluating tenders for purchase of a drilling rig and pumping equipment to improve the Niue water supply.

HYDROGEOLOGY OF TARAWA ATOLL, KIRIBATI - A FOREIGN AID PROJECT by G. Jacobson.

On behalf of the Australian Development Assistance Bureau, a study of the hydrogeology of Tarawa atoll, in the Gilbert Islands, Kiribati, began in September 1980 in collaboration with Department of Housing & Construction personnel. The study is part of a feasibility investigation for the improvement of the Tarawa water supply.

Tarawa is a coral atoll consisting of 20 narrow islands surrounding a central lagoon which is open to the ocean on one side. Several of the islands contain freshwater lenses which overlie salt water. Some of the lenses are already used for water supply for Tarawa's 20 000 people. The objective of the current investigation is to extend knowledge of groundwater resources contained in the lenses, and prove up additional lenses that could be brought into production.

The investigation includes drilling boreholes to investigate the subsurface geology, the permeability of the strata, and the depth of freshwater in the lenses. To the end of October, six boreholes had been completed out of a programmed 14. A typical section through the atoll shows coral sand and gravel to a depth of several metres overlying buried coral reef, which overlies an older limestone at a depth of 15-20 m. The freshwater lenses appear to be up to 30 m thick. Detailed salinity profiles are to be measured, so that the lenses can be modelled in order to assess their long-term stability, especially in periods of drought.

A.C.T. URBAN GEOLOGY STUDIES

DALTON TO CANBERRA NATURAL GAS PIPELINE by R.W. Evans

An engineering geological assessment of the route for the proposed natural gas pipeline from Dalton NSW, to Canberra (A.C.T) was carried out during July and August at the request of the Pipeline Authority. The pipeline, 273 mm in diameter, is to be buried in a trench 1.25 to 2.00 m deep, 0.60 m wide, and 57 848 m long.

The route passes through Ordovician metasediments, Silurian shales and ashflow tuffs, and Siluro-Devonian granodiorite.

The proposed route traverses soil for about 47 720 m, or 82%, of its length. Rippability of the ground to be excavated was assessed and reported in the investigation report. The trench will lie above the regional water-table, except near the Yass River, but will encounter inflows from perched lenses within the surficial cover. Excavations are generally expected to be stable.

ENGINEERING GEOLOGY, AND OTHER MAPS OF CANBERRA by G.A.M. Henderson

1:10 000 Engineering Geology Maps

Work continued on the preparation of maps in the 1:10 000 engineering geology of Canberra series. The notes for the Woden-Weston Creek and Belconnen maps were written, and a small amount of new data was added to the compilations of these maps. Excavations for a building near Bruce Stadium (North Canberra Sheet) were mapped.

The current (October 1980) state of progress of the six maps is as follows:

Coppins Crossing	-	published
Central Canberra	-	map compilation and notes complete, with map editors
Woden/Weston Creek	-	map compilation and notes complete, with map editors
Belconnen	-	map compilation and notes complete
North Canberra	-	map compilation at an advanced stage
South Canberra	-	map compilation in progress

1:50 000 Canberra and Queanbeyan Geological Map

The map is in press. Accompanying notes have been written to introduce the reader to the geology of the area; they describe several traverses, with notes on the rocks and formations encountered. Geological notes dealing with the stratigraphy of the area will be issued as a Record (1979/80).

ENGINEERING GEOLOGY OF CANBERRA: A SYNTHESIS by G.A.M. Henderson

A start was made on preparation of maps and figures for a paper on the engineering geology of Canberra, to be written in collaboration with E.J. Best Canberra College of Advanced Education. The paper is for submission to the Association of Engineering Geologists, for inclusion in their new series entitled 'Cities of the World', dealing with the fundamental geological, geotechnical, hydrological, and seismological factors influencing the founding, growth, and continuing development of the world's cities.

Notes on the geology of the site of the Australian National University were provided by G.A.M. Henderson to Mr Jules Knight, for inclusion in a history of the ANU campus.

E.K. Carter supplied notes to Mr W.C. Andrews on the geological setting of the A.C.T., for incorporation in a publication on the engineering development of Canberra, to be published by the Institution of Engineers, Australia.

SURFICIAL STRATIGRAPHY IN THE SOUTHERN TUGGERANONG VALLEY, A.C.T. by J.R. Kellett

Seven major soil sequences (pedoderms) were mapped and described in two pediplain basins at Lanyon station. Cross-sectional field relations are shown in Figure G2.

The Rob Roy pedoderm is buried deep beneath the Lanyon north basin and is composed of lithic and feldspathic quartz arenites of ancient braided streams that drained alluvial fans.

The Murrumbidgee pedoderm is composed of a basal fanglomerate facies, with distinctive relict complex cutans overlain by massive sands with strong pseudogley patterns of multidirectional veins and joint planes. The pedoderm represents an active period of fan building with early dominant fluviatile influences followed by sheet flooding during maturity, probably during the Late Tertiary.

The Tuggeranong pedoderm has a basal fanglomerate overlain by intensely mottled fine sands on which a dense, plastic clay has developed. Sedimentary structures in the basal fanglomerate indicate dominant fluviatile conditions a progressively drier climate is indicated by the accumulation of aeolian dust and carbonate-bearing montmorillonitic clay in the B2 horizon and subsolum.

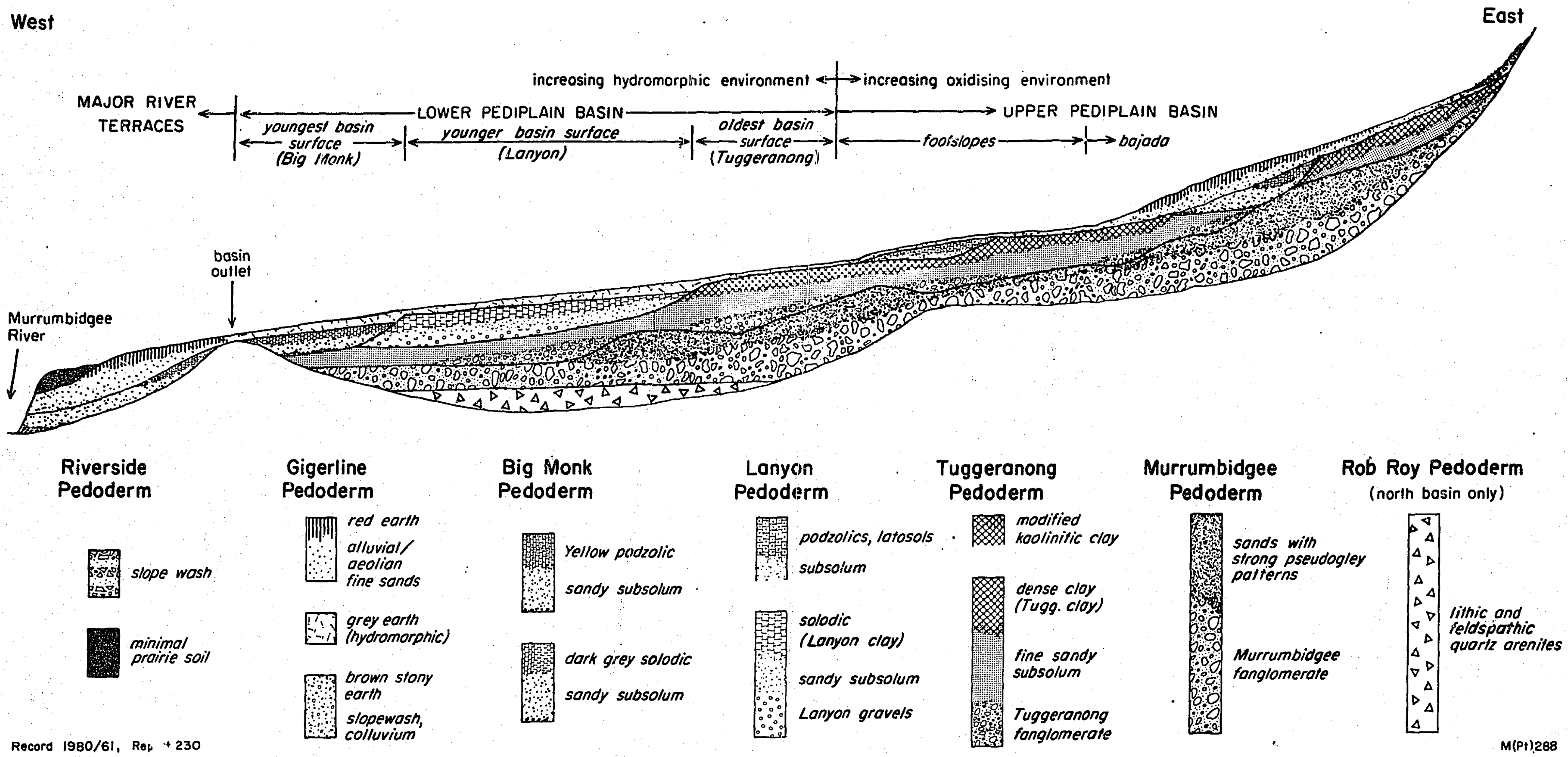


Fig. G2 Schematic cross-sectional relationships of pedoderms in the Lanyon Basins. Length of section about 3 km.

The Lanyon pedoderm was deposited after a period of vigorous planation in the basins, and minor hillslope denudation. The sequence is composed of open shoestring gravels (basal clastics facies) overlain by floodplain sands and silts on which podzolics and latosols developed in well-drained areas and solodic soils developed under hydromorphic conditions. The pedogenetic environment was characterised by greatly increased leaching capacity which produced clays and hardpans rich in kaolinite, gibbsite, goethite, and hematite, and which also desilicated exposed hillslope sections of the Tuggeranong pedoderm.

The Big Monk pedoderm was marked by large-scale hillslope denudation and by secondary planation of the Lanyon and Tuggeranong pedoderms in the basins. The Big Monk pedoderm is composed of slopewash sediments overlain by a yellow podzolic soil with a distinctive bleached A2 horizon. The pedoderm appears to be contemporaneous with modification of the pediments to incipient cryoplanation terraces during a periglacial maximum characterised by severe frost shattering during dry winters and extensive sheetwash during wet spring periods. Pedogenesis was under conditions of mild leaching, but secondary partial saturation occurred during the moister stable phase of the subsequent pedoderm.

The Gigerline pedoderm was probably initiated by a return to cold conditions, accompanied in part by strong westerly winds which deposited sands on some westerly slopes. The pedoderm is composed of brown to grey earths developed on colluvium, and in some places on aeolian sands. Exhumed boulder trains on southwesterly facing slopes indicate dry winters with effective frost wedging at the free face, followed by spring or summer rains of high enough intensity to promote large mud flows.

The Riverside pedoderm, a minimal prairie soil restricted to alluvial terraces, hardly affected the basin surfaces, but extensive slopewash sheets were deposited above 800 m above sea level.

The youngest pedoderms may be correlated with the K-cycle soils of the Molonglo River valley at Canberra. Equivalence is based on the degree of organisation of the soils and the relative positions in the terrace sequences of the Murrumbidgee and Molonglo River. The proposed correlation is:

K1 - Riverside pedoderm
K2 - Gigerline pedoderm
K3 - Big Monk pedoderm

Correlation of the older pedoderms cannot be made with confidence at this stage.

GINNINDERRA SEWER TUNNEL (P.H. Vanden Broek)

A report was written on the geology of the completed tunnel, and on the features of engineering geology concern - overbreak, drilling and excavation rates of advance, water inflows, support requirements, and lining. It will be issued as a Record. Geology and engineering conditions were generally as predicted: overbreak was slightly greater and support used slightly less than forecast. Water inflows did not create any serious difficulties.

ENGINEERING GEOLOGY ELSEWHERE

TELECOM TUNNELS, MELBOURNE by E.G. Wilson

The Australian Telecommunications Commission is augmenting the telephone network in the Melbourne Central Business District by constructing at shallow depths five small-diameter tunnels which interconnect with the existing underground cable system. The Department of Housing and Construction (DHC), Victoria-Tasmania region, designed the project and is supervising construction by Codelfa Construction Pty Ltd and Cogefar Construction Pty. Ltd. in joint venture. The project geologist, G. Trand, was provided by DHC; his work was supervised by E.G. Wilson, who also advised DHC on engineering geological aspects of the project.

The Queen Street tunnel, 255 m long, has been completed; the Lonsdale, Russell, and Exhibition Street tunnels, totalling 1584 m, have been excavated, and concrete lining of the tunnels is in progress. An Alpine Miner tunnel-excavation machine was used throughout, except for the shafts and small sections where access was limited.

QUEEN STREET TUNNEL

The excavations passed through three rock types from three different units. The units and a fourth underlying unit are each separated by unconformities.

Ferruginous sandstone	Brighton Group	
unconformity		
Basalt	Older volcanics	TERTIARY
unconformity		
White to pale grey silty clay	Werribee Formation	
unconformity		
Weathered mudstone	Dargile Formation	SILURIAN

The highly irregular contact between the white silty clay and the overlying basalt was a major feature of the tunnel exposures (Fig. G3).

Mudstone of the Dargile Formation was encountered in the lower levels of drillholes during the design investigation; however, because of the poor invert conditions that were expected in the extremely weathered mudstone at the initially proposed invert levels, it was decided to raise the invert level, and the mudstone was successfully avoided.

The geological summary log (Fig. G3) is presented for the Queen Street tunnel as a longitudinal section, and the description of materials is set out in tabular form.

Werribee Formation

The white silty clay of the Werribee Formation was comparatively firm on excavation, and had a moisture content ranging from 10.2 to 17.2 percent. Tests at the face for moisture content gave a guide to stability of the material, an increase in moisture content being associated with a decrease in stability.

The clay was friable and did not stick to the cutter head of the Alpine Miner. The tunnel was supported by steel sets, 1 m apart, with full timber lagging of the crown and walls.

The silty clay in the invert was generally stable and did not require the setting of invert slabs.

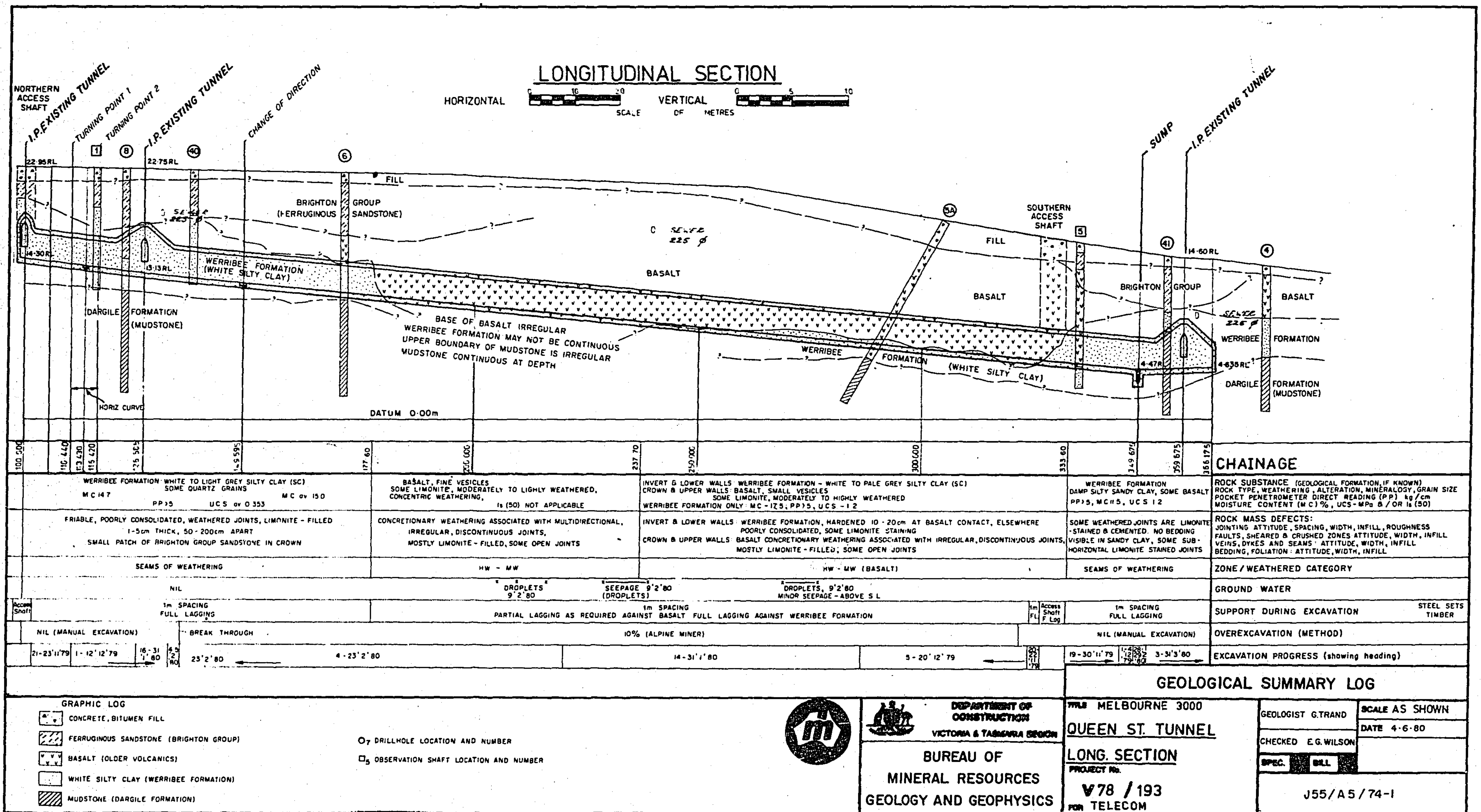
Basalt

The basalt is in part vesicular, and columnar jointing is common. Although it is extremely weathered, the concretionary ferruginous structure and limonite cement along all joints imparted to the rock mass in openings a stability greater than would normally be expected for rock in an extremely weathered condition.

Support consisted mainly of steel sets at 1 m spacing with timber lagging as required; in general, half lagging was placed in the crown, and minimum lagging for installation of the sets was placed along the walls.

Brighton Group

Brown to grey, ferruginous clayey sand of the Brighton Group was penetrated in the northern access shaft overlying white silty clay (Werribee Formation), and in a small area in the crown of a nearby chamber. These sections were fully supported and lagged.



Record 1980/61, Report 230

Fig. G3 Longitudinal section of Queen Street Telecom tunnel, Melbourne, showing geology and engineering conditions encountered.

LONSDALE, RUSSELL, AND EXHIBITION STREET TUNNELS

The main tunnel runs east-west along Lonsdale Street, and the other short tunnels connect it with the old tunnel system. All the tunnels have been excavated and concrete lining of the tunnels is in progress. The summary geological logs of these tunnels have not yet been completed.

A total length of 1584 m has been excavated, through:

1264 m of mudstone with fine-grained sandstone interbeds	Dargile Formation	Silurian
30 m of basalt overlying white silty clay	Older volcanics over Werribee Formation	Tertiary
85 m of clay and silty clay	Elizabeth Street Formation	Quaternary
205 m of silty clay and sandy clay	Colluvium at Russell St	Quaternary

The basalt and white silty clay at the western end of the Lonsdale Street tunnel is similar to that described in the Queen Street tunnel.

Dargile Formation

The excavated Dargile Formation consisted of extremely to moderately weathered mudstone with fine-grained sandstone interbeds. Bedding, cleavage, and most major faults and shears intercept the tunnel line at an angle greater than 45 degrees in the Lonsdale Street tunnel and at an acute angle in the Russell and Exhibition Street tunnels.

Excavation by the Alpine Miner proceeded without problems, apart from causing dust when excavating moderately weathered rock.

Rock defects such as joints and bedding did not promote instability, except in the extremely weathered mudstone where clay-filled joints are common. The sealing by limonite cement of almost all defects in highly to moderately weathered rock contributed greatly to tunnel stability. Support installed in variably weathered mudstone is summarised as follows:

Degree of weathering	Steel sets spaced 1 - 1.5 m centres Crown lagging	Wall lagging
Extremely weathered	Full	Full to half
Highly weathered	Half	Less than half
Moderately weathered	Less than half	Set spacers only

Elizabeth Street Formation

This dominantly heavy-clay formation lies within a depression in the top of the mudstone; its base is about 1.5 m above sea level. The clay has a relatively high moisture content, but its permeability is so low that no free water entered the tunnel during construction.

Steel sets at 1 m spacing and full lagging were placed throughout; invert slabs were also laid to provide a firm footing for the rails of the muck train. The clay adhered to the cutting head of the Alpine Miner and also had a tendency to aggregate on the conveyor belts.

Colluvium at Russell Street

The colluvium encountered was a damp stiff silty clay that was above the water-table. Some perched aquifers caused seepages, but dampness was not a problem in the tunnel. Support was provided by steel sets at 1 m spacing with full timber lagging.

METHODS OF STABILITY ASSESSMENT

The methods of Bieniawski (1974)* and Barton & others (1974)** were used to assess rock quality, stand-up times after excavation, and support systems. Two main observations were made relating to the application of these methods.

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* In ADVANCES IN ROCK MECHANICS. Proceedings of 3rd ISRM Congress, 2A.

** Rock Mechanics, 6, 189-236.

(i) The extremely weathered basalt was a consistently stronger rock mass than had been expected, and for many forms of tunnel construction, it would not have required support. Its strength is derived from the tightly packed arrangement of the concretions in the weathered basalt and the limonite cement in defects.

(ii) Highly to moderately weathered mudstone was also stronger than expected, and in most projects would not have required support. This is because the rock mass is reinforced by a strong limonite cement along the bedding planes, joints, and all other defects. In extremely to highly weathered rock, the advent of clay seams ensures that joints become a plane of weakness, and the support estimates for such a rock mass were satisfactory.

Of the two systems, that of Barton & others was more easily applied to most materials; however, the application of either of these methods depends greatly upon the qualitative assessment of the various rock parameters by the observer, and his experience will always be a major factor in their successful application. The major value of the method of Barton & others is the development of a variety of support systems for various tunnel conditions, and these provide numerous options for the variation of support with changes in tunnelling conditions.

The project will be completed in mid-1981, and the completion reports for both tunnels are in preparation.

<u>FLOWERDALE GRAVEL DEPOSIT, TASMANIA</u> by G. Jacobson

At the request of the Department of Administrative Services, a gravel deposit at Flowerdale, in northwest Tasmania, was inspected. The deposit is on Commonwealth land, purchase of which is being negotiated with the State Government. Reserves of gravel were estimated by inspection, pending a more detailed subsurface investigation to be undertaken by the Tasmanian Mines Department.

<u>MANS STUDY</u> by E.K. Carter

Written comments were given to the Secretariat of the Major Airport Needs Study (MANS Study) group, which is concerned with the siting of a second major airport for Sydney. The comments related to geotechnical aspects of several sites, including the likelihood and effect of the possible sterilisation of known resources of coal and clay. Mining engineers also participated in the formulation of advice.

ENVIRONMENTAL STUDIES

GENERAL by E.K. Carter

In addition to the studies referred to above, e.g. Alligator Rivers hydrogeology study (NT) and groundwater pollution studies in the A.C.T., several activities related to environmental issues. Two environmental impact statements (or similar documents) relating to uranium mining in the Alligator Rivers region were reviewed and commented on (Professional Opinions Geol. 79.033 and 80.005). Members of the Section sat on two interdepartmental committees concerned with the disposal of radioactive waste, and participated in two seminars.

DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE by E.G. Wilson

A study of the research being undertaken overseas into the disposal of high-level radioactive waste in geologic formations is being undertaken by Dr J.M. Costello (AAEC) and E.G. Wilson. The BMR rock mechanics and engineering study is concerned with:

(1) the composition and forms of radioactive wastes;
(2) the migration of waste products in solution;
(3) the fixation of waste in geological materials;
(4) the dissipation of waste-generated heat from repositories in geological formations;
(5) the permeability of host rocks under consideration for repositories; and
(6) the assessment of repository efficiency in the long term.

The study commenced in April 1980, and the acquisition and study of reference material is continuing.

Wilson attended the Radioisotope Course for Graduates, No. 26, from 21 July to 15 Aug 1980, at the Australian School of Nuclear Technology at Lucas Heights.

MAP EDITING AND COMPILATION

by

G.W. D'ADDARIO

STAFF: G.W. D'Addario, P.D. Hohnen (to 22 November 79), J.E. Mitchell (on LWOP since 19 June), A.J. Mikolajczak, R. Chan, B. Holden (from 2 April to 9 May), M.J. Fetherston (from 19 August).

MAP EDITING

Eighteen maps were edited as follows:

1:250 000 Geological Series - colour edition - 7 maps: Mount Anderson, Paterson Range, Anketell, Port Hedland, Munro, Mandora, McLarty Hills (the last three were edited by Sedimentary Section officers).
1:100 000 Geological Series - colour edition - 4 maps: Reynolds Range, Mundogie, Duchess Region, Dajarra.
1:10 000 Engineering Geology Series - 1 map: Central Canberra
1:50 000 geological maps - 1 map: Canberra, Queanbeyan and Environs.
1:500 000 geological maps - 2 maps: Ngalia Basin geology, Ngalia Basin structure.
1:1 000 000 geological maps - 1 map: Officer Basin.
1:1 000 000 continental shelf sediments maps - 1 map: Tasmania and Bass Strait.
Editing is in progress on 8 maps:
1:250 000 Geological Series - colour edition - 4 maps: Alice Springs (2nd edn) Yarrie (2nd edn.), Napperby (2nd edn), Alligator River (2nd edn).
1:100 000 Geological Series - colour edition - 3 maps: Strangway Range, Lawn Hill, Nabarlek Region.
1:500 000 geological maps - 1 map: southern Prince Charles Mountains.

MAP COMPILATION

Advice was given, as required by authors and draftsmen, on various aspects of map compilation.

BMR EARTH SCIENCE ATLAS OF AUSTRALIA

The Atlas, which is a loose-leaf publication consisting of maps of sheet-size about 57.5 x 33.5 cm each with an accompanying sheet of commentary, was launched in December 1979 with 5 maps. Topics issued were: Structural elements, Bouguer gravity anomalies, free-air gravity, plate tectonics, and earthquakes. The general geology topic was subsequently released. Other maps have been printed and await their accompanying commentaries.

Contributions within the group included the revision of the commentaries for the Cainozoic and weathering map, and the surface drainage and continental margin map.

Other sections within BMR have made progress with the preparation of maps and notes on sedimentary sequences; petroleum and oil shale geology; coal; and on geophysical topics.

The Earth Science Atlas Committee, which advises on development of the Atlas, has prepared a report recommending future courses of action.

ATLAS OF AUSTRALIAN RESOURCES, 3RD SERIES (produced by Division of National Mapping).

Geology of Australia, 1:5 000 000. Under G.W. D'Addario's direction, the face of the map was revised to distinguish moderate to high-grade metamorphic rocks and to incorporate recent information. In consultation with DNM officers, a simplified reference was adopted. W.D. Palfreyman began to prepare a commentary for the map. The atlas and notes will include data from rock-types and structural elements maps prepared for the BMR Earth Science Atlas.

COMMISSION FOR THE GEOLOGICAL MAP OF THE WORLD

Metamorphic Map of Australia 1:5 000 000. This project is under the direction of Professor T.G. Vallance, University of Sydney, who will produce the supporting commentary. The map compilation group produced a revised compilation which was displayed at the 26th IGC in Paris in August. The map will proceed to fair drawing when the compilation is approved by Professor Vallance and the commentary is received.

Geological Atlas of the World: Sheet 15. Arrangements have been made to write notes for the map, which covers Australasia and the adjoining region at scale 1:10 000 000, and which has already been printed by the Commission for the Geological Map of the World.

INDEXES AND MINERAL REPORTS

by

K. Modrak & E.K. Carter

STAFF: K. Modrak, L. Kay, J. Morrissey (part time), T. Pedersen (11 March - 21 May), P. Kennewell (resigned 3 June), R. Lorenz (commenced 7 October).

STRATIGRAPHIC INDEX

Literature on Australian geology received through the BMR Library was indexed under the headings - author, State, 1:250 000 Sheet area (1:100 000 if appropriate), detailed location, basin/structural province, keywords, and stratigraphic names, and was entered onto the GEODX data base. In particular, all references to stratigraphic nomenclature were recorded.

All literature indexed since December 1978 is now available on GEODX. Current indexed literature is entered on a monthly basis to the data base via terminals from data sheets; average input is 67 references containing 520 established and new stratigraphic names.

Literature indexed before December 1978 is being systematically entered on to the GEODX data base under contract. The initial contract project relates to author cards, containing references and stratigraphic names, for literature published during 1970 or later. The first contract, carried out between April and June, covered author cards beginning with letters A and B; this covered 635 references with 4396 stratigraphic names. The next contract (for 1980/81) should be twice as large.

As a result of the extra input, the data base is rapidly expanding, and in the period May/June it was transferred to a larger IMAGE System, resulting in more efficient storage and retrieval programs.

All new published stratigraphic names are still manually added to the Register of Stratigraphic Names and all references to these and previously published names are typed onto the card indexes in an abbreviated form. The intention is to phase out the latter this year and to generate, via the computer, the former in about two years' time. It is estimated there are about 26 500 names in the Register of which about 40% are on GEODX.

Some 310 new stratigraphic names, 171 of which were previously reserved, and 269 definitions of units were indexed in the period to 30th September. Two hundred and thirty five new names were reserved, and 80 definition cards submitted by authors through Divisional Stratigraphic Nomenclature Subcommittees of the Geological Society of Australia, were filed.

Six bimonthly Variation Lists (Nos. 36-41) and one annual Deletion List (No. 7) noting additions to and deletions from the Central Register, were compiled and distributed to Stratigraphic Nomenclature Subcommittees, to State Geological Surveys, to Universities and to mineral exploration companies.

Inquiries and visits from authors, State Survey officers, and others regarding stratigraphic names, definitions, and literature references were dealt with.

Mrs. R. Lorenz, a qualified librarian, joined the group early in October. Her experience in databases and information retrieval is being directed towards promoting GEODX as an inhouse data base for literature on Australian geology.

E.K. Carter prepared, on behalf of the Stratigraphic Nomenclature Committee of the Geological Society of Australia, a draft 'Field geologists' guide to lithostratigraphic nomenclature in Australia'. The guide includes an annotated copy of chapters 2-7 of the ISSC's 'International Stratigraphic Guide', and Australian interpretations and procedures. Chapters on the nomenclature of igneous and metamorphic rocks have been added by the committee. The guide is at present being considered by Society members.

TECHNICAL FILES

No new data were added to the technical files, which have now been inactive for three years, but staff were assisted as necessary to locate information held in the files. The files consist of one or more folders for each 1:250 000 map Sheet area, containing mainly unpublished data and newspaper cuttings.

MINERAL REPORTS

FLUORITE GEOLOGY PROJECT

P.J. Kennewell continued the study by literature search and study of airphotographs, of the occurrence, geological setting, mineral associations and genesis of fluorite deposits, until his resignation in June. He prepared a comprehensive compilation, which will be produced after editing as a data Record, on the occurrence of fluorite in Australia. He also prepared a paper in which he postulated a model for the deposition of fluorite. His thesis is that fluorine is derived from the mantle and is brought to the surface by mantle-upwelling at seafloor-spreading centres and by mantle plumes. The presence of alkaline igneous rocks and tensional tectonic features - e.g., grabens and autocogens, particularly 'triple junctions' - may (amongst other features) therefore be indicators of fluorine-rich areas.

MUSEUM

by

J.D. Reid

STAFF: D.H. McColl (to 26.11.79), J.E. Price (to 16.11.79), J.D. Reid, M.S. Amar (part time)

For most of the year Mr Reid has had sole responsibility for the running of the Museum; in this time, essential routine activities particularly public relations functions, have been maintained.

COLLECTIONS

The BMR collection has increased in number by about only 30 specimens. The combined value of the specimens acquired is over $5000.

Some outstanding specimens were given to the Acting Director in November while visiting China; most notable is a large stibnite group. Other exceptional donations were a suite of prehnite and babintonite specimens collected in Antarctica by D. Wyborn and some display pieces of Australian jade from the mining company Jade Australia Ltd.

A large (2.3 kg) specimen of the Mundrabilla meteorite and a specimen of bismuthinite from the Hatches Creek wolfram field, N.T., were acquired by exchange.

Purchases were limited to a calcite specimen and an atacamite crystal group. Both are exceptional museum pieces.

EDUCATION

Ten school groups visited the museum. Many groups were so large that visits were confined to the 2nd floor meeting room, where specimens and diagrams were prepared in advance. This arrangement has proved most successful and has facilitated the presentation of specifically requested topics - usually Australian economic geology. Mrs. E. Young, of Information Subsection, has contributed substantially to the organisation and presentation of these educational sessions.

SERVICES TO VISITORS OTHER THAN SCHOOL GROUPS

Mineralogical, gemmological, and petrological enquiries continued at about the same level as in previous years. Many local amateur mineralogists and miners are regular visitors.

Gemstones are regularly brought in for identification. Visitors who request an accurate valuation are referred to local jewellers.

Approximately 400 visitors were recorded. Many visitors are now coming in with specific enquiries and know in advance about our different collections.

EXHIBITIONS

The Museum continued its participation in the regular Gem and Mineral shows. The Gemboree at Perth attracted very many visitors. The BMR display was very well received.

The A.C.T. Lapidary Club, Glen Waverley (Victoria), and Adelaide Gem and Mineral Club shows were all excellent. Large numbers of visitors were recorded and the BMR exhibits were greatly appreciated.

At all these shows the mineralogical content is noticeably rising. Many dealers are now exclusively marketing minerals and gemstones and many lapidarists are progressing into the minerals field.

The annual seminar of the Mineralogical Societies of New South Wales and Victoria was held in Melbourne in June. The theme for this year was 'Gold'. The seminar was successful in its involvement of amateur and professional mineralogists, museum personnel, and mineral dealers.

TRANSIT ROOM by M.S. Amar

The number of samples submitted by field parties and sent to contractors or to BMR laboratories for chemical analysis, thin sectioning, or other determinations, in the period 1st October, 1979 to 30 September 1980, was (comparative figures for the same period last year in brackets):

Normal thin sections	5759	(3368)
Polished thin sections	352	(576)
Impregnated thin sections	47	(21)
Standard thin sections	303	-

Isotopic age determinations (various)	132	(224)
Chemical analyses (various)	4744	(3448)
X-ray diffraction determinations	37	(3)
Other	-	(10)
Total	11374	(7641)

CONFERENCES AND COURSES

Members of the Section attended the following training courses and conferences:

G. Jacobson	Australian Water Resources Council Remote Sensing Workshop, Canberra, November 1979.
E.G. Wilson	Australian National Committee on Large Dams Annual Field Conference, Latrobe Valley, Vic., 3-6 December 1979.
G. Jacobson	International Symposium on the Hydrology of Areas of Low Precipitation, Canberra, 10-13 December 1979.
E.K. Carter E.G. Wilson	Department of National Development and Energy's Seminar on 'Disposal of Tailings from Mining and Milling Uranium Ores' Canberra, 13 February.
E.K. Carter E.G. Wilson R.W. Evans	Centre for Resource and Environmental Studies, ANU, Workshop on Alligator Rivers Region, Canberra, 17-18 April.
E.K. Carter	Third Australia New Zealand Geomechanics Conference, Wellington, N.Z., 12-16 May, and post-conference tour of South Island, 17-22 May.
K. Modrak	Austalian Geoscience Information Association/Sydney Mineral Exploration Discussion Group, Sydney, 3 June.
J.D. Reid	Annual joint meeting of the Mineralogical Societies of N.S.W. and Victoria, Melbourne, 7-8 June.
R.W. Evans	Australian Water Resources Council Groundwater Recharge Conference, Townsville, 14-18 July.
E.G. Wilson	Australian School of Nuclear Technology, Radio Isotope Course for Graduates, No. 26, Lucas Heights, N.S.W., 21 July - 15 August.
R.W. Evans	Government Engineering Geologists' Urban Geology Workshop, Brisbane, 15-18 September.

Participation in gem and mineral exhibitions is given in the section titled 'Museum'.

MULTIDISCIPLINARY PROJECTS

Project Manager: G.E. Wilford

McARTHUR BASIN PROJECT

Compiled by

K.A. Plumb, Project Co-ordinator

STAFF: W. Anfiloff[2], K.J. Armstrong[1], C.D.N. Collins[2], J.P. Cull[2], T.H. Donnelly[3], J.M. Fetherston[1], J.W. Giddings[2], D. Gregg[1], M. Idnurm[2], M.J. Jackson[1], I.B. Lambert[3], M.D. Muir[1,4], J. Pinchin[2], K.A. Plumb[1], C.J. Simpson[1], A.G. Spence[2], R. Tracey[2], M.R. Walter[1].

1. Geological Branch.
2. Geophysical Branch
3. CSIRO
4. Resigned during year

The basic aim of the McArthur Basin Project is to elucidate the evolution of the McArthur Basin, using stratigraphic, sedimentological, geochemical, geophysical, tectonic, and other studies, and to apply this information to the understanding of the genesis of ore deposits in the region and to the assessment of possible hydrocarbon potential of the basin.

Most staff only contribute to the project on a part-time basis. Geological studies were seriously curtailed by the resignation from BMR of M.D. Muir, in February 1980. The only fieldwork during 1980 was a small gravity survey, to complete some unfinished lines from the 1979 survey. The emphasis during 1980 has been on geological laboratory investigations and data compilation, and the interpretation of geophysical data.

With the recent completion of data processing and map compilation of all the airborne data obtained by Geophyscial Branch over the McArthur Basin, the project is about to enter an important phase: a multidisciplinary synthesis and interpretation of all geophysical data over the whole McArthur Basin.

OBJECTIVES OF 1980 PROGRAM

The main tasks of the 1980 program were to:

1) Continue laboratory studies and data interpretation of the sedimentology and palaeogeography of the Wollogorang Formation, Masterton Formation, Mallapunyah Formation, and Amelia Dolomite;

2) Continue laboratory studies and data interpretation of the sedimentology, palaeogeography, and micropalaeontology of the Balbirini Dolomite, Dungaminnie Formation, and their stratigraphic equivalents;
3) Carry out Pb-isotope measurements of carbonate rocks from the McArthur Group, to assess the source of metals in the McArthur Pb-Zn deposits;
4) Carry out mineralogical and geochemical studies of samples from the Eastern Creek Pb-Ba deposit;
5) Continue investigations of the application of LANDSAT data to mapping and mineral exploration in the McArthur Basin;
6) Continue laboratory measurements on magnetostratigraphic samples collected during 1978;
7) Interpret data from the 1978-79 crustal-seismic, magnetotelluric, and gravity surveys;
8) Complete unfinished gravity lines from the 1979 survey.

REPORTING OF RESULTS

1. Progress of research has been regularly reported in Quarterly Reports - Records 1979/82 and 1980/5, 38, and 55.
2. Muir (1980) has presented palaeontological evidence for the Early Cambrian age of the Bukalara Sandstone (BMR Journal 5, 159-160).
3. Muir, Armstrong, & Jackson (in press) have described Precambrian hydrocarbons in the Looking Glass Formation (BMR Journal 5, 301-304).
4. A synthesis of the stratigraphy, structure, and evolution of the McArthur Basin and Mount Isa regions, by Plumb, Derrick, & Wilson (1980), has been published by the Geological Society of Australia, in 'Geology and Geophysics of Northeastern Australia'.
5. Jackson (1980) presented aspects of McArthur Basin sedimentology to the 4th Australian Geological Convention in Hobart, and to a M.Sc. Seminar at James Cook University.
6. A Record by Cull, Spence, Major, Kerr, & Plumb, describing the 1978 magneto-telluric survey, is being edited.
7. Anfiloff's Record, describing the 1978-79 gravity survey, is being edited.

GEOLOGY

(M.J. Jackson, Task Leader)

STUDIES OF DRILLCORE MATERIAL (M.J. Jackson, M.D. Muir, K.J. Armstrong)

BMR Bauhinia Downs 4 (M.D. Muir, K.J. Armstrong)

Petrological studies of the 25 m of Looking Glass Formation intersected in Bauhinia Downs 4 indicate that the formation has undergone a complex sequence of post-depositional events, including 1) early vadose alteration of the original carbonates, producing vuggy porosity, 2) extensive silicification and the development of additional porosity, 3) sulphide mineralisation (including pyrite, chalcopyrite, and marcasite), and 4) trapping of oily material in vugs and veins. The oily material comprises black hard bitumen in the form of globules, pore filling, or as fracture coatings, and a brownish liquid which liberated hydrocarbons during pyrolysis. The presence of hydrocarbon residues in 1600 million year old rocks indicates that Proterozoic basins should not be ignored in the search for hydrocarbons.

Australian Geophysical MA1 and MA2 holes (M.J. Jackson)

Core from these holes, drilled in the Mountain Home area (lat. 17°00'S long. 136°30'E) in 1966, were examined at the Department of Mines in Darwin. The sequence comprises Amelia Dolomite, Mallapunyah Formation, and the upper part of the Masterton Formation, rather than just Amelia Dolomite, as described in the company report. The Amelia Dolomite is of similar thickness and lithology to that in the type section (60 km to the west) indicating that the alternating intertidal to supratidal environments in which the unit was deposited extended well to the east of the McArthur River area. The Mallapunyah Formation is also of similar lithology to that in the type area, near Mallapunyah, but it is reduced in thickness from 150 m to 80 m.

BMR Mount Young 2 (M.J. Jackson)

Detailed petrological and geochemical studies of the Wollogorang Formation in BMR Mount Young 2 (drilled in 1979) were started. In Mount Young 2, the Wollogorang Formation is 132 m thick, and consists of an upper interval of fine to coarse-grained sandstone, overlying a thick sequence of dolomitic siltstone and claystone. The distinctive stromatolitic bioherms, present near the base and top of the formation to the south and east of this area, were not found, although the lower part of the drillhole did penetrate the 'ovoid' marker beds, characteristic of the formation elsewhere. Three intervals of breccia, interpreted as solution collapse or slump breccia, were intersected; these beds appear to be closely related to contorted beds of dolomite after evaporites.

The lower part of the formation comprises a 70 m-thick interval of laminated grey to black pyritic shale, which resembles the mineralised HYC Pyritic Shale Member of the Barney Creek Formation, the host to the McArthur River Pb-Zn-Ag deposit. A geochemical comparison between the Wollogorang Formation in this drillhole and drillhole sections of the HYC Pyritic Shale Member, as reported by I.B. Lambert (Journal of Geochemical Exploration 2, 307-330, 1973) has been undertaken to assess the base-metal potential of the Wollogorang Formation. Metal values throughout the drillhole are surprisingly low, even though there are apparently rich sections of visible disseminated sulphides. Copper values range from 2-1500 ppm, lead from 5-95 ppm, zinc from 5-55 ppm, and silver from 0-2 ppm. There are no anomalous zinc levels, but the highest (anomalous) copper and lead values occur near the base of the ovoid beds. There appears to be a relationship between the base-metal concentrations and the organic carbon content, which is highest (6%) in the lower part of the ovoid beds. Although containing some of the features that Lambert considered attractive when prospecting for shale-hosted stratiform base-metal deposits (i.e., pyritic black shales, vitric tuff bands, ferroan dolomites) the formation lacks the major zinc and lead anomalies that Lambert considered to be diagnostic of significant mineralisation.

Evaporite minerals (M.J. Jackson, M.D. Muir)

From a visual comparison with textures seen in newly discovered Cambrian evaporites from the Officer Basin in South Australia, pseudomorphs after trona (hydrous sodium carbonate) and shortite (sodium-calcium carbonate) have been tentatively identified in surface samples of chertified carbonates from the Lynott Formation and Balbirini Dolomite. In the modern environment, trona and shortite are restricted to non-marine lacustrine environments.

MINERAL DEPOSIT STUDIES

Lead-isotope tracer studies - McArthur Group (I.B. Lambert, Baas Becking Geobiological Laboratory)

The aim of this study is to directly assess the source of metals in the McArthur deposits by comparing the Pb-isotope compositions of the ores with those of trace Pb in McArthur Group rocks stratigraphically beneath these sediment-hosted deposits. Potential source rocks must have Pb that is isotopically compatible with the ore Pb. The work was undertaken at the Federal Institute for Geosciences, Hannover, in collaboration with Dr Axel Hohndorf. Final interpretation must await the completion of further analyses and the following summary is based on a preliminary assessment of the results to hand.

Present indications are that:

(i) The bulk of the carbonate-rich samples have Pb that is much more radiogenic than ore galena (after correction of measured present-day results, on the assumption that the rocks have remained closed systems to U and Pb since the Middle Proterozoic).

(ii) Residues left after reaction of the rocks with hot 2N HCl (i.e. feldspars, quartz, zircons, some phyllosilicates, etc.) have very radiogenic present-day Pb isotope ratios. However, when corrected for the concentration of U recovered from these samples, the calculated Pb isotope ratios at the time of ore formation are impossibly low in some cases. It is obvious that, for these residues, there has been over-correction for the U-supported radiogenic Pb generated since accumulation of the McArthur Group. The reason for this is uncertain at present, but possibilities include U addition since the Proterozoic, radon loss from the sedimentary rocks, or differential leaching of U and Pb during recovery of the metals by acid treatments.

Eastern Creek lead-barite deposit (T.H. Donnelly, Baas Becking Geobiology Laboratory; M.D. Muir, K.J. Armstrong)

Previous work has indicated that the barite occurrences are widespread, and appear to be related to the pre-Limmen land surface. The host rocks are very shallow-water or non-marine dolomite and chert of the Kookaburra Creek Formation. The deposits are both cross-cutting and conformable. A complex mineral paragenesis is indicated. Copper minerals are usually associated with the galena, and the galena and barite mineralisation appear to be essentially different events (Record 1979/16).

Preliminary isotope studies during 1980 indicate fairly constant $\delta^{34}S$ values for the barite (av. +18.0 $^{o}/oo$), whilst a chalcopyrite sample has a ^{34}S value of +21.0 $^{o}/oo$ and a galena sample +11.2 $^{o}/oo$. Dolomite has fairly constant ^{13}C and ^{18}O values (av. +1.1 and 21.8 $^{o}/oo$, respectively). Both ^{13}C and ^{18}O values are in agreement with a sedimentary marine (or modified marine) origin.

LINEAMENT ANALYSIS OF THE EMU FAULT ZONE (J.M. Fetherston)

An analysis of the lineaments along the Emu Fault Zone is in progress using two different methods of remote sensing. The study area is a 50 km wide strip, extending 220 km north-south along the fault zone, in the Bauhinia Downs and Mount Young 1:250 000 Sheet areas.

Data are being compiled from conventional RC9 black and white aerial photography, at 1:80 000 scale, and from computer-enhanced, multiband, black and white Landsat imagery at 1:1 000 000 scale. Lineament data are acquired from both types of imagery, both by vertical viewing and by low-angle oblique examination.

The objectives of the project are:

(i) To compare the lineament data which can be acquired from conventional aerial photography with that acquired from Landsat imagery, in a semi-arid region;

(ii) To carry out a cost-effectiveness analysis of the two systems of remote sensing, based on the results obtained from each method versus the time taken to extract the data;

(iii) To attempt to locate the extension of the Emu Fault Zone beneath the Cainozoic cover in the northern half of the study area;

(iv) To detect, by remote sensing techniques, relative horizontal displacement of blocks along the fault zone.

Compilation of data is almost complete, and a preliminary evaluation of the analysis is in progress.

PALAEOMAGNETISM

(M. Idnurm (Task Leader), J.W. Giddings)

Following the derivation of a tentative first order magnetostratigraphic column in 1978 and 1979, attention was focussed in 1980 on the origin of the remanence in the upper Tawallah to middle McArthur Group sequences of the Kilgour River. For magnetostratigraphy to be valid, the remanence must be either depositional or immediately post-depositional, with no more than a few hundred thousand years delay. Similarly, for palaeomagnetic pole determinations, there exists a maximum acceptable time lag which, for the relatively poorly defined Precambrian pole path, is a few million years. Unfortunately such time lags are often difficult or impossible to estimate, and at best only general self-consistency tests can be applied.

The Kilgour River sequences show no evidence of metamorphism, but two types of post-depositional processes that could result in remagnetisation have taken place in the region. These are the extensive mineralisation in the eastern part of the region (possibly hydrothermal solutions), and karsting.

Two lines of evidence were examined in the Kilgour River sequences. The first was the direction of the remanence within a large drag-fold that is associated with a prominent fault in the upper Masterton Formation. The magnetisation was found to contain two stable components. One of these had an intermediate to high blocking temperature range with a fairly sharp cut-off at 400° to 450°C, and a direction that had not previously been observed in the Kilgour River sequences. The fold test indicated that this component does not antedate the folding, and on the basis of its direction and blocking temperature characteristics it was interpreted to have been acquired as a result of frictional heating during faulting. On this assumption, the age of the regional block-faulting was deduced to be either 500 or 750 m.y.

The second component has a high blocking temperature, and a direction similar to the remanence direction found in a weathered zone on the boundary between the Masterton and Mallapunyah Formations. This component lies close to the axial plane of the fold and consequently a sensitive fold test could not be applied. From field relationships it seems likely however that the weathered zone, and hence the magnetisation, antedates the folding.

The second line of evidence is the variation of remanence directions within the Kilgour River sequence. These directions should change progressively up-sequence, unless late-stage magnetic overprinting has taken place - for example, by Tertiary weathering or diagenesis. The results indicate a more or less progressive change, though several large and abrupt directional changes occur within the sequence. These are provisionally interpreted as major depositional breaks. Each abrupt change appears to coincide with a recessive unit, making it difficult to verify the depositional breaks in the field.

The evidence therefore tends to rule out late-stage magnetic overprinting of the remanence. Future measurements, in finer detail, on the existing collection of samples should define the time constraints for the remanence acquisition more closely.

The evidence that is now accumulating from the Kilgour River sequences points to a major error in the Australian middle Carpentarian pole path. A new path has been tentatively constructed, and will be confirmed and refined with additional measurements on the sample collection.

SUBSURFACE STRUCTURAL INVESTIGATIONS

During 1978-79, a geophysical profile was obtained right across the southern McArthur Basin by integrated crustal seismic, magnetotelluric, and gravity surveys (Fig. D1). The aim of the surveys was to objectively test the present geological model for the Batten Trough by obtaining information on the deep structure across the basin, particularly across the Emu Fault and across the poorly exposed area immediately to the east of the fault.

The emphasis during 1980 has been on interpretation and analysis of these data, and most of this work is entering its final stages. A major activity was a preliminary attempt to integrate the analysis and interpretation of these data; the results were presented at the Ninth BMR Symposium in April, 1980. Although this represented only a first attempt at a total interpretation, and is subject to modification, it has provided very significant constraints to the geological models which are possible (see SYNTHESIS), despite apparent disagreements which exist between the interpretations provided by individual methods.

SEISMIC SURVEYS (C.D.N. Collins, J. Pinchin)

Two long-range seismic refraction traverses were recorded during June-July 1979 east and west of the Emu Fault (Fig. D1). Deep vertical reflection recordings were made at each of the six shot-points, and at a site at Starvation Hill. Both traverses were about 300 km long, and each comprised 34 recording stations. The first traverse was between Daly Waters and HYC mine, along the

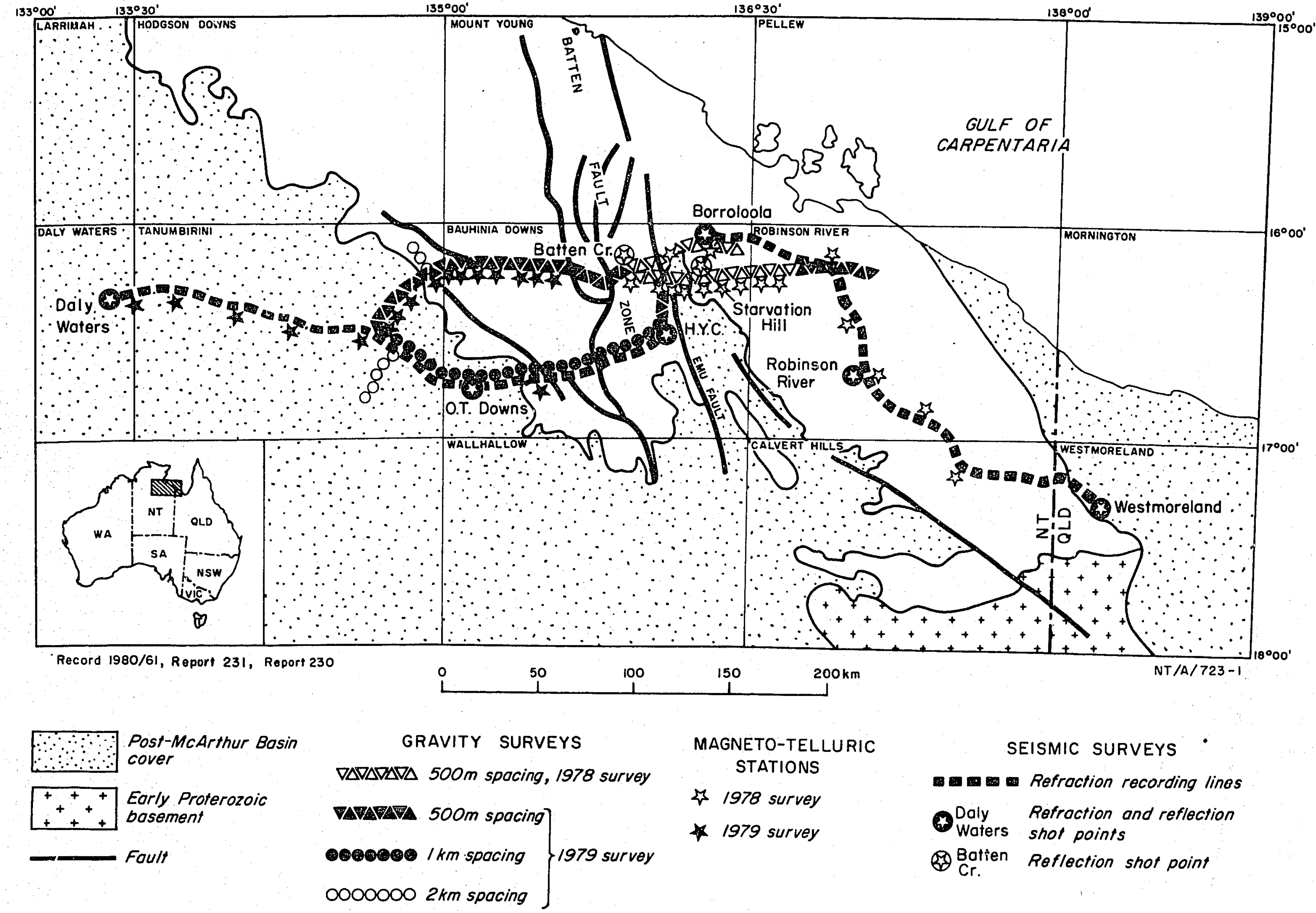

Fig. D1 Locality map, geophysical surveys, southern McArthur Basin, 1978 - 79, showing 1:250 000 Sheet areas

Carpentaria Highway. Two large shots of 2000 kg each were located at Daly Waters and HYC respectively. Two smaller shots of 400 kg each were fired at HYC and 100 km west of HYC, near OT Downs. For the larger shots, the station spacing was about 15 km, while for the smaller shots, the spacing was about 5 km. A similar pattern was recorded along the second traverse, east of the Emu Fault, with large shots at Borroloola and Westmoreland, and smaller shots at Borroloola and Robinson River.

This data has now been processed and preliminary interpretations have been made. Analysis of refraction data is still proceeding.

Good vertical reflections were recorded at all sites except Daly Waters and OT Downs (Record 1979/57). Reflections were recorded down to depths of about 45 km, and Moho reflections correlate well with the refraction data. A characteristic strong reflection band east of the fault correlates with a 6.39 km/s sub-basement refractor, and appears also to the west of the fault, near the HYC mine, but is displaced upwards by 1.8 km (Record 1980/38). The basement appears to be 3.9 km deep west of the fault at HYC, and 5.7 km deep east of the fault at Starvation Hill. From these reflection results and stratigraphic control provided by the McArthur Group to the west of the fault, the Tawallah Group is interpreted as thinning towards the Fault Zone.

The refraction data between Daly Waters and OT Downs shows a wedge of low-velocity (4.6 km/ s) material, 4 km thick at Daly Waters, pinching out just east of OT Downs (Record 1980/38). This probably consists mainly of Cambrian rocks of the northern Georgina Basin, covered by thin Mesozoic sediments. Below this the refractor velocity is 5.6 km/s, and probably represents the Roper Group. Between HYC and OT Downs, the surface refractor velocity is 5.9 km/s. This high velocity is probably due to the known thick carbonates of the McArthur Group, and masks any deeper refractors.

The structure to the east of the Emu Fault is different. A 5.98 km/s refractor can be correlated with the reflection basement of the McArthur Basin succession. Below this a dipping 6.39 km/s refractor correlates with the strong vertical reflections, mentioned above.

There appear to be prominent gradients in the lower crust, where the velocity increases from about 7.9 km/s to perhaps 8.3-8.4 km/s at the Moho. These high velocities are based on recordings made at the end stations of the long traverses, and are therefore not well defined. However, the lack of strong wide-angle reflections from the Moho requires the velocity gradients to occur over a broad zone. A maximum depth for this gradient zone of 55 km fits the data fairly well, but an extension of the recordings beyond 300 km is desirable to properly interpret the data.

MAGNETOTELLURICS (A.G. Spence, J.P. Cull)

During October-November 1979, all 17 sites which had been planned for the 1979 season were occupied. The northern line, recorded up to mid-October (Fig. D1), was designed to supplement gravity data, with the aim of determining the deep structure beneath the Bauhinia Shelf. Subsequent stations (not on Fig. D1) were occupied along the Carpentaria Highway to supplement regional seismic refraction surveys. The quality of data was generally acceptable, despite extreme weather conditions, although three of the sites were affected by thunderstorm activity. Comprehensive results are not yet available. Final inversions and interpretations will be carried out after the data have been screened for systematic error. Processing will be completed in 1981 and the results integrated and interpreted along with the 1978 data.

During 1980, the data from the 1978 survey (see Annual Summary for 1979, BMR Report 222) was re-evaluated and reinterpreted. Qualitative examination of the data conclusively demonstrates a totally different resistivity structure to the east and west of the Emu Fault. These differences have been quantitively detailed by further 2-D modelling (Record 1980/38), designed to 1) test the susceptibility of the models to different starting assumptions; 2) extend the models to greater depth and eliminate some anomalies from earlier models (Record 1979/57).

The different starting models did produce differences in detail in the model, but they did not alter the principal conclusions of the earlier model (Record 1979/57), or of the qualitative assessment of the data.

To the east of the Emu Fault, the further modelling has confirmed a conductive sequence about 4.5 km thick, clearly representing the Tawallah Group, above a resistive basement. There is no indication of any significant body of resistive rocks that may correlate with the McArthur Group.

To the west of the Emu Fault, a layered sequence of highly resistive rocks about 4.5 km thick is confirmed at the top of the sequence, overlying a conductive unit. However, this conductive layer is now shown to be about 4 km thick and to overlie a resistive basement. The upper resistive rocks clearly correlate with thick carbonates of the McArthur Group, which crop out at the surface, and the conductive layer beneath correlates with the Tawallah Group.

The magnetotelluric modelling is clearly in agreement with the Batten Trough model as predicted from geological evidence.

GRAVITY (W. Anfiloff, R. Tracey)

During July-August, 1980 detailed gravity traverses were extended westwards along the Carpentaria Highway to Daly Waters, southwards along the Stuart Highway to Newcastle Waters, along part of the Buchanan Highway, and along the Beetaloo Road. The data have yet to be processed.

Interpretation of the 1978-79 surveys (Fig. D1) has been completed, and a BMR Record is being finalised. The data have produced a good qualitative picture of broad structure across the southern McArthur Basin, and have also delineated many of the local structures.

The main structural forms delineated are broad undulations in the basement, and the basement gradually deepens westwards from Robinson River to Tanumbirini. No major faults are identified in the eastern part of the survey area, including the Emu Fault. Major faults are identified over a wide zone to the west of the Emu Fault, but the anomalies do not exceed 15 mGal,, and are not sufficiently distinctive to provide an accurate indication of basement depth. Some of the fault displacements are known to be of the order of kilometres, so the density contrast across thebasement is unlikely to be greater than 0.1 g/cm^3. Considerable uncertainly remains with repect to formation densities, in the absence of suitable calibration by either a deep drillhole or seismic reflection data.

The Emu Fault appears to be the locus of only minor upfaulting, which in some areas may have elevated dense mineralised layers. Major displacements are not apparent from the gravity data, suggesting that the mineralisation may therefore have occurred in a tectonically inactive area.

SYNTHESIS (K.A. Plumb)

The presently available data provide some very specific constraints:

1) Both seismic and magnetotelluric data indicate a major, deep-seated discontinuity at the Emu Fault;
2) Both seismic and magnetotelluric data indicate a thick sequence of McArthur Group to the west of the Emu Fault (in agreement with geology), while the Tawallah Group is indicated as being the principal sequence to the east, with no indication of any appreciable thickness of McArthur Group;

3) Gravity indicates that there is little or no aggregate mass difference across the Emu Fault. This implies (but does not prove) a lack of any significant structural displacement or change in stratigraphy at the fault.

Figures D2.1 and D2.2, taken from the BMR Symposium lecture, illustrate alternative cross-sections which may be constructed across the Emu Fault (EF). The depths of the stratigraphic units were defined by alternative selections of seismic reflections and magnetotelluric soundings as at April 1980, and by interpretation of surface geology. The density contrasts used in the gravity modelling were derived by analysis of reasonably well-known structures in the Batten Fault Zone. However, subsequent analysis (see GRAVITY) has indicated that the particular density contrasts selected may be wrong, although better figures are still not available. Similarly, further I-D magnetotelluric modelling and detailed seismic refraction analysis are proceeding, which may further modify the sections.

Despite these probable modifications to the models, the variations are expected to be limited and certain conclusions may be derived at this stage:

1) The combined geophysical and geological data can definitely be combined into a single compatible interpretation;
2) The combined data constrain possible geological models within definite limits, and will probably continue to do so;
3) The present integrated model clearly favours the geologically predicted model for the form of the Batten Trough.

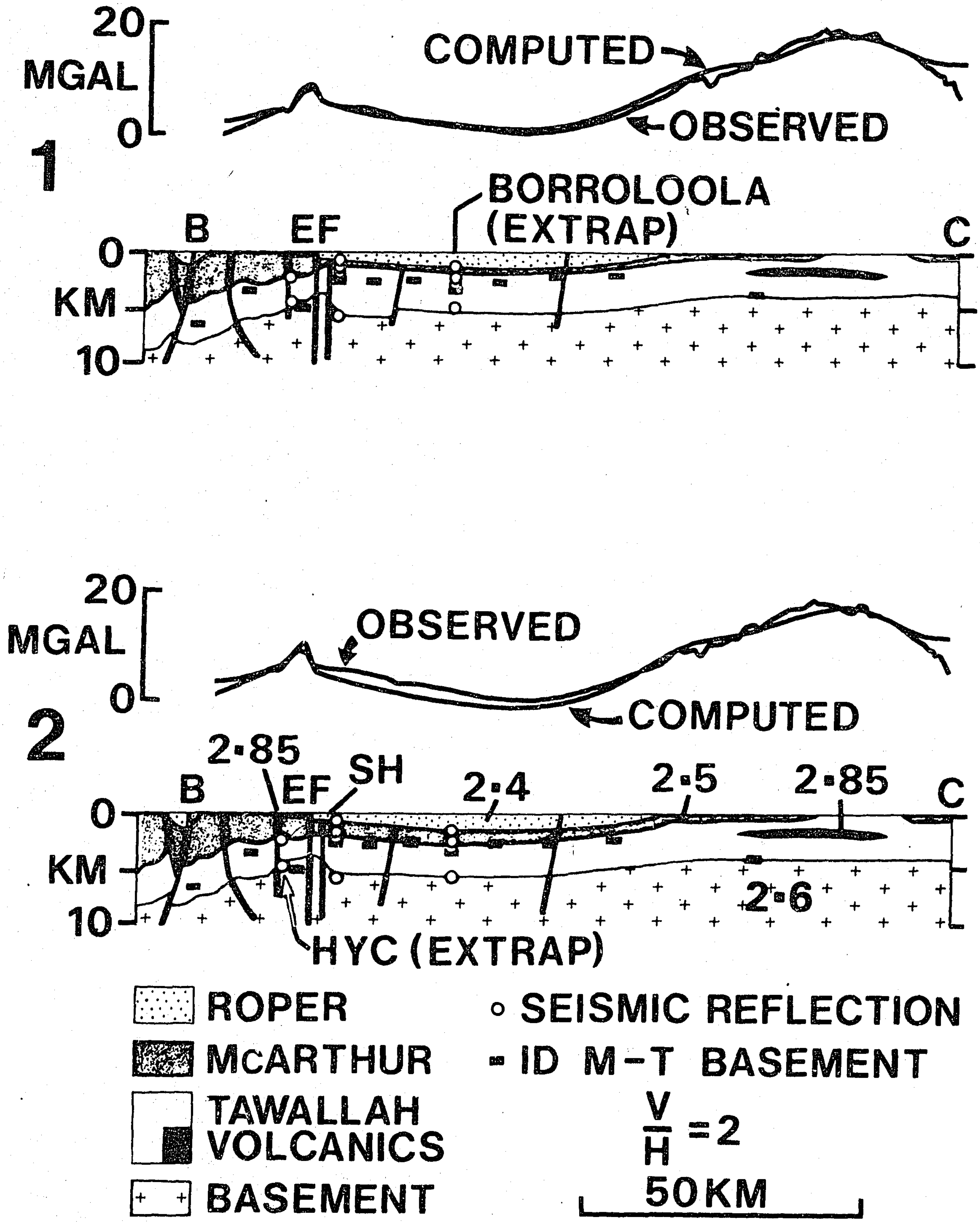

Fig.D2 Integrated structural section across Emu Fault, from combined preliminary geophysical and geological data (from BMR Symposium 1980)

GEORGINA BASIN PROJECT

Compiled by

C.J. Simpson (Acting Project Co-Ordinator)

STAFF: The following personnel (listed alphabetically) have contributed to the multidisciplinary project during 1980:

P.E. Balfe (Geological Survey of Queensland, GSQ), J.J. Draper (GSQ), E.C. Druce (Dept Trade & Resources), P. Duff, R.A. Fortey (British Museum), D. Gibson, P.M. Green (GSQ), P.L. Harrison (Alliance Oil Development), K.A. Heighway, A. Hutton (Wollongong University), K.S. Jackson, P.J. Jones, P.D. Kruse (Sydney University), I.N. Krylov (Geological Institute, Moscow), K.G. McKenzie (Riverina College of Advanced Education), M.D. Muir (CRA Exploration), R.S. Nicoll, W.V. Preiss (Geological Survey of South Australia, GSSA), B.M. Radke, J.E. Rees, J.H. Shergold, C.J. Simpson, P.N. Southgate (ANU), S. Turner (Queensland Museum), M.R.Walter, P. West (ANU).

GENERAL

The Georgina Basin Project was initiated in 1974, and was programmed to run for five years. It has served as a pilot study for multidisciplinary projects in BMR. During 1979/80, emphasis has been laid on completing the publication of results of completed field-oriented geological and geophysical activities in the basin. These have laid the framework for a series of more specific studies which have been proposed for a second phase of research in the basin.

During the last 12 months 23 papers and three 1:100 000-scale maps were released, bringing to 75 the total number of papers produced since 1974, and to 5 the 1:100 000-scale maps issued. A review paper summarising the activities and achievements of the project for the period 1974-79 was produced by J.H. Shergold and issued as BMR Record 1980/34 (MF 131).

STRATIGRAPHY AND SEDIMENTOLOGY (Figure D3)

by

J.J. Draper, P.M. Green, P.E.Balfe, P. Southgate, B.M. Radke

The Ethabuka Sandstone is a recently recognised Ordovician unit in the Georgina Basin. Sublabile to quartzose sandstone with minor mudstone, siltstone, and pebbly beds crop out along the inner margin of the Toko Syncline

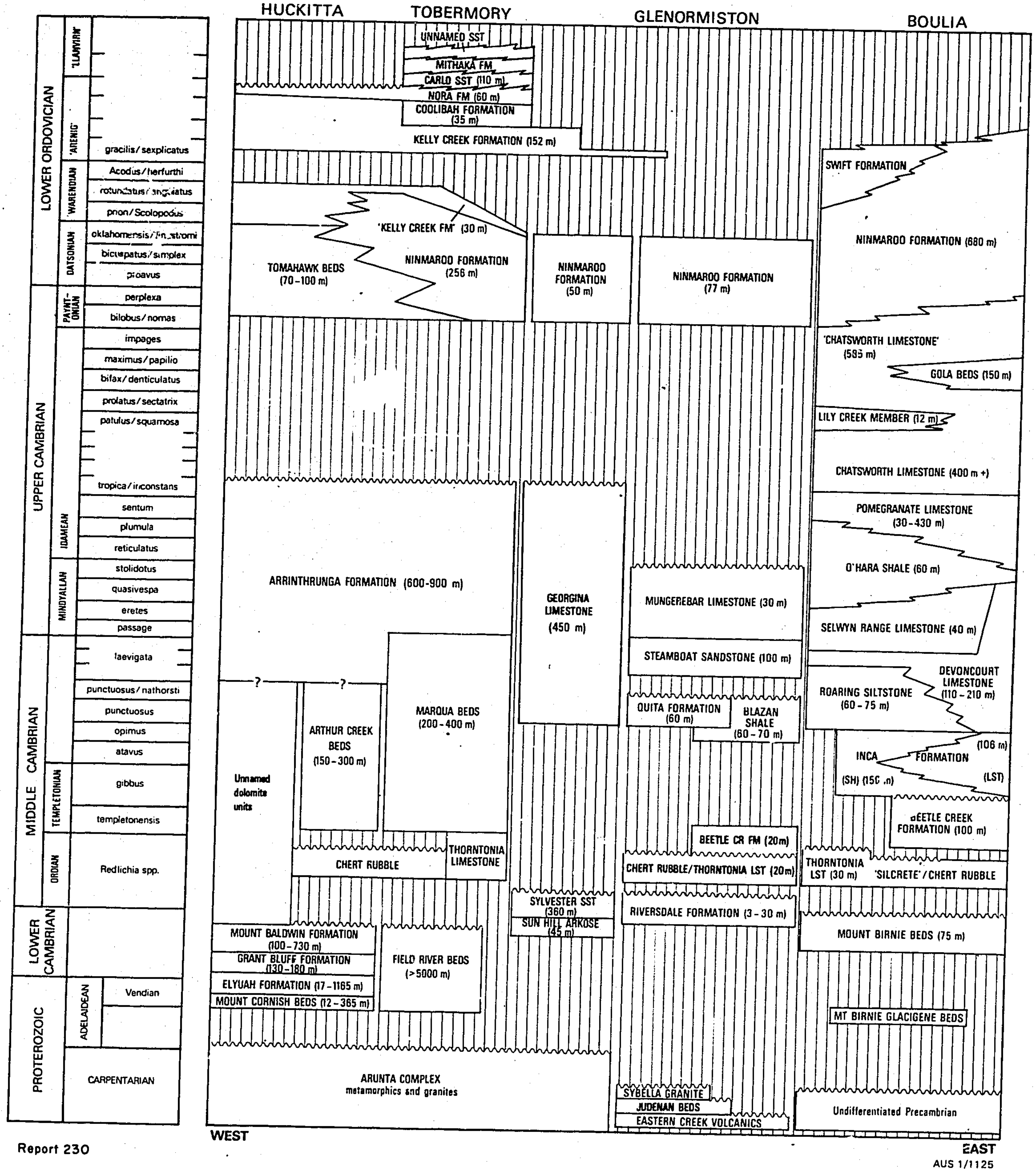

Fig. D3: Correlation of rock units in the southern part of the Georgina Basin and were intersected in the subsurface in AOD Ethabuka No. 1. It is a marine unit containing trilobites, nautiloids, pelecypods, gastropods, and brachiopods. Numerous inorganic and biogenic sedimentary structures are present. It conformably overlies the Mithaka Formation and unconformably underlies Devonian and Mesozoic rocks. The lowermost part of the unit is transgressive; this depositional phase was apparently followed by progradation, so much of the upper part of the unit may be non-marine. Since the Ethabuka Sandstone is lithologically similar to the Nora Formation, Carlo Sandstone, and Mithaka Formation, it has been included with them in a redefined Toko Group, from which the Coolibah Formation has been excluded.

The Coolibah Formation is removed from the Toko Group on lithological grounds. It is dominantly a carbonate unit; the carbonates are generally fine-grained and of algal origin. In contrast, the Nora Formation and the overlying units are siliciclastic rocks except for some skeletal limestones in the Nora Formation, which is transgressive on the Coolibah Formation. It is therefore considered that the Coolibah Formation does not have sufficient lithological features in common with the Nora Formation and overlying units to warrant its inclusion in the Toko Group.

Between July and November 1977, the Queensland Department of Mines drilled two deep stratigraphic bores (Mount Whelan 1 and 2) in the Mount Whelan 1:250 000 Sheet area. The two holes provided a cored section through the southeastern Georgina Basin sequence on the eastern flank of the Toko Syncline. Overlap between the two holes was not obtained and as a result the section from the upper Georgina Limestone to the lower Ninmaroo Formation was not cored. With this exception, a complete and virtually fully cored section was obtained from the Carlo Sandstone (Lower to Middle Ordovician) to Proterozoic granitic basement.

Gamma-ray log correlations between GSQ Mount Whelan 1 and 2, and the petroleum exploration wells PAP Netting Fence 1 and AOD Ethabuka 1, were carried out during 1980.

The Nora Formation thickens from 114 m in PAP Netting Fence 1 to 232 m in AOD Ethabuka 1 and 235 m in GSQ Mount Whelan 2. A similar trend of increasing thickness from north to south has been noted by Draper for the Carlo Sandstone. A sharp increase in gamma-ray response over the lower part of the

Nora Formation allows correlation between PAP Netting Fence 1 and GSQ Mount Whelan 2. In both these wells, a limestone interval occurs near the base of the formation.

The Coolibah Formation is a readily identifiable unit throughout the area, but its thickness varies irregularly, ranging from a minimum of 28 m in GSQ Mount Whelan 2 to a maximum of about 80 m in AOD Ethabuka 1.

The Kelly Creek Formation thickens markedly from 110 m in PAP Netting Fence 1 to 241 m in GSQ Mount Whelan 2, and shows some facies variations. In GSQ Mount Whelan 2, an interval of dolomitic, pelletal sandstone forms the uppermost part of the Kelly Creek Formation. This upper unit is not developed in PAP Netting Fence 1, where the bulk of the formation comprises dolostone, which is equivalent to the dolostone of the middle unit in GSQ Mount Whelan 2. In AOD Ethabuka 1, a very thin sandstone sequence overlies dolostone and forms the top of the formation. The lowermost of the three subunits in GSQ Mount Whelan 2 is a sequence of sandstone and limestone with subsidiary dolomite, which is transitional in character with the upper Ninmaroo Formation. A similar sequence forms the basal part of the Kelly Creek Formation in PAP Netting Fence 1. The basal part of the Kelly Creek Formation was not drilled in AOD Ethabuka 1.

A sharp break in the gamma-ray log near the top of the Ninmaroo Formation is present in both GSQ Mount Whelan 2 and PAP Netting Fence 1. In each hole, interbedded sandstone and limestone with variable dolomite content forms the upper part of the unit. The clastic content of the unit decreases downward in both holes. The base of the Ninmaroo Formation was not intersected in GSQ Mount Whelan 2, but a number of correlatable gamma-ray log events indicate that relative rates of deposition between PAP Netting Fence 1 and GSQ Mount Whelan 2 were fairly uniform. From this it may be deduced that the base of the Ninmaroo Formation would lie at about 1050 m at GSQ Mount Whelan 2.

For PAP Netting Fence 1, the lithostratigraphic nomenclature of the Cambrian section has not been firmly established, because various workers have applied different subdivisions. Draper & others (1978)* recognised the sequence above the Thorntonia Limestone as Marqua beds and overlying Arrinthrunga Formation. Harrison (1979)** subdivided the Arrinthrunga Formation in PAP Netting Fence 1 into the Steamboat Sandstone and overlying Georgina Limestone. In GSQ Mount Whelan 1 the Georgina Limestone section intersected is equivalent in age to virtually the entire post-Thorntonia Limestone, pre-Ninmaroo Formation section in PAP Netting Fence 1. This assessment is based on the presence of

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* BMR Record 1978/10

** APEA Journal 19, 30-42.

fossil assemblages of the Glyptagnostus reticulatus Zone at 195.0 m near the middle of the Georgina Limestone in GSQ Mount Whelan 1, and the probable occurrence of a similar fauna at 1497 m in PAP Netting Fence 1 near the base of the Arrinthrunga Formation. Assemblages from near the base of the Georgina Limestone in GSQ Mount Whelan 1 and from near the base of the Marqua beds in PAP Netting Fence 1 are of similar age. It seems, therefore, that the section in PAP Netting Fence 1 is fully represented by a thinner, deeper-water facies equivalent in GSQ Mount Whelan 1. The sandy middle portion (Steamboat Sandstone) of the PAP Netting Fence 1 section, which may represent deposition in beach shoal or barrier-bar environments, is not developed in GSQ Mount Whelan 1.

The interval with high gamma-ray response below the Georgina Limestone in GSQ Mount Whelan 1, the Inca Formation correlative, is not obviously developed in PAP Netting Fence 1. There is, however, an increase in the gamma-ray response over the basal part of the Marqua beds.

The Thorntonia Limestone is a prominent low feature on the gamma-ray logs of both holes. The underlying units in GSQ Mount Whelan 1 are not developed in PAP Netting Fence 1, where the Thorntonia Limestone directly overlies granitic basement.

Phosphatic hardgrounds have been found within the Thorntonia Limestone near Riversleigh, Thorntonia, and D-Tree in the Undilla area, and at Rogers Ridge in the Burke River Structural Belt. A similar, non-dolomitised, phosphatic hardground sequence is present in the Currant Bush Limestone (Ptychagnostus atavus age) 3 km south of Thorntonia.

In the Riversleigh area west of the Gregory River, cauliflower chert nodules occur within the Thorntonia Limestone about 24 m above the Precambrian/Cambrian unconformity. The nodules are in a recrystallised dolomite 2 m thick, and are interpreted as pseudomorphs after anhydrite nodules. The nodules have a relict lath fabric and abundant $CaSO_4$ inclusions indicative of a primary anhydrite precursor. Phosphatic hardgrounds both underlie and overlie the anhydrite nodules, which according to D.J. Shearman (Imperial College, personal communication, 1979) indicate subaerial sabkha diagenesis. Further evidence of either subaerial exposure or semi-emergent conditions was not observed because primary sedimentary structures have been obliterated by dolomitisation, recrystallisation, and stylolitisation. Lateral tracing of this unit during the 1980 field season provided further evidence of emergent and semi-emergent conditions in areas of lesser diagenetic overprinting.

Recent investigations suggest that the intraformational conglomerates present in the Georgina Limestone were formed by the reworking of early lithification nodules within the sediment. An alternative explanation for the formation of the nodules is that they resulted from tectonic stress of the limestone. The features likely to form by this process include microstylolite swarms, pervasive solution dolomitisation, and stylolites. It is considered that the relationship exhibited by the nodules to the surrounding sediments can result from early lithification processes, and subsequent modification by tectonic stress.

The diagenetic history of the Cambro-Ordovician Ninmaroo Formation has been delineated using optical and cathodoluminescent petrographic techniques.

Diagenetic phases are:

1) Eogenetic phase, characterised by early aragonitic cementation, variable but generally minor dolomitisation, and emplacement of evaporitic sulphates.
2) Early telogenetic phase, established during subaerial emergence, and accompanied by significant dissolution of sulphates and some aragonitic carbonate and partial silicification of remnant sulphates.
3) Mesogenetic phase with burial, when continued silicification and extensive dolomitisation were followed by later contemporaneous hydrocarbon migration, saddle dolomite, and minor sulphide (pyrite, galena, sphalerite) emplacement. Calcite, fluorite, barite and anhydrite precipitated. Pressure solution continued and accelerated towards the end of this phase.
4) Late telogenetic phase, characterised by extensive dedolomitisation, the dissolution of late mesogenetic sulphate, carbonate dissolution to form cavern porosity, and additional silicification.

The late telogenetic phase was the most prolonged in most areas except the central Toko Syncline and deeper structures in the Burke River Structural Belt. Mesogenetic events were commonly intermittent with this phase where deeper and warmer connate waters rose, escaping through the near-surface telegenetic porosity.

PALAEONTOLOGY

Palaeontological studies continued throughout the year. Bulletin 186, by J.H. Shergold, on the Late Cambrian trilobites from the Chatsworth Limestone, was published, as were papers on: Early Ordovician ichnofossils from the Mithaka Formation (J. Draper), new taxa, palaeobiography and biological affinities of Middle Cambrian Bradoriida (Crustacea - P.J. Jones & K.G. McKenzie); Middle Cambrian Bradoriida (Ostracoda - K.G. McKenzie & P.J. Jones) and discussion on the Archaeocyatha of the Georgina and Amadeus basins (P. Kruse & P. West).

GEOCHEMISTRY

PETROLEUM SOURCE ROCK STUDIES, by A. Hutton, P.M. Green, P.E. Balfe, K.S. Jackson, B.M. Radke.

Petroleum source rock investigations continued during the year. Follow up drilling was carried out in three holes in the Camooweal, Duchess, and Tobermory areas. The first two holes were aimed at assessing the distribution of the oil shale detected within the Inca Shale intercepted in Mount Isa 1 (near Camooweal) in 1978. Though organic matter and hydrocarbons were detected in the 1980 drilling no true oil shales were recorded.

Petrographic and alginite content evaluation were undertaken on the oil shale from Mount Isa 1 hole. The lamellar alginite in the oil shale from Mount Isa No. 1 is similar to the lamellar alginite of Tertiary age from Rundle, Queensland (termed alginite B by Hutton & others, 1980)* and was probably derived from green or blue-green algae. There is, however, a much higher percentage of humic-related macerals in the Mount Isa 1 oil shale than in Rundle oil shale. The origin of this humic-related organic matter is not known. Although it resembles vitrinite in higher rank coals it cannot be derived from higher plant matter since it is of too great an age (early Palaeozoic or older). The percentage of alginite B is lower than would be expected for an oil shale which is stated to yield 81 litres per tonne. Oil shales from Rundle with a similar yield have about 25% by volume alginite B. This apparent anomaly between yield and alginite content could result from one of three factors -

1. Alginite B from Mount Isa 1 may yield more shale oil per unit volume than alginite B from Rundle.
2. The sample examined may have a lower alginite content than the sample assayed.
3. The vitrinite-like material has affinities with bituminite, and may yield more oil than vitrinite derived from higher plant matter.

There is insufficient evidence to ascertain the environment of deposition of the oil shale from Mount Isa 1. However, the presence of pyrite indicates a reducing environment during or after diagenesis. Further studies are needed to determine vertical variations, if ~ ·thin the oil shale seam.

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* APEA Journal, 20, 44-67.

In GSQ Mount Whelan 1 and 2 weak indications of solid and gaseous hydrocarbons were recorded. Solid bituminous hydrocarbons were noted filling pore space in limestone of the Coolibah Formation in GSQ Mount Whelan 2. In view of the similar occurrences in AOD Ethabuka 1 and PAP Netting Fence 1, the interval including the lower Nora Formation and the Coolibah Formation is considered to be the most prospective for heavy hydrocarbons.

The average organic carbon contents of the Georgina Limestone (0.54% based on 34 analyses) and the Thorntonia Limestone (0.44% based on 3 analyses) compare favourably with the organic carbon values of 0.47% of petroliferous (0.16% for non-petroliferous) carbonate provinces of the Russian Platform. The worldwide average organic carbon content for limestones is 0.20%. However, the good source potential of these limestones may be downgraded by their evident lack of permeability. Although the generation of gaseous hydrocarbons from such sources seems possible, it is doubtful whether significant liquid hydrocarbon accumulations will be found.

Elemental analysis of extracted kerogens from Mount Whelan 1 cores are considered of dubious value because of high ash content which seems related to a high S content. This relationship has not yet been explained. Gas chromatography of saturated hydrocarbon fractions shows no evidence of thermal immaturity. In conjunction with vitrinite reflection data from AMDEL, it indicates that both Cambrian and Ordovician rocks are mature, though the Middle Cambrian Thorntonia Limestone may be overmature.

The extensive dolostone unit of the Lower Ordovician Kelly Creek Formation in the Toko Syncline has variable porosity and permeability, and significant potential as a hydrocarbon reservoir. The porous dolostone intersected in GSQ Mount Whelan 2 is 107 m thick. Measured porosities from the unit averaged 11%, while averaged horizontal permeability (gas) was 234 md, and vertical permeability (gas) 28 md. Permeability is more variable vertically, being generally low but with randomly distributed higher values. Porosity is dominantly intercrystalline in mottled and stratified distribution, with associated vug, channel, fracture, and breccia types. The porosity developed late in diagenesis, during and after pervasive dolomitisation of the sequence. The sequence contains live hydrocarbons indicating migration after late dolomitisation. Fluorescence intensity and colour of acritarchs in some samples suggests that the Lower and middle Ordovician section is oil-mature. This confirms similar conclusions drawn from reflectance data in the same sequence. The traces of liquid hydrocarbons in the dolostone, and previously reported gas flows from the overlying sandstone in AOD Ethabuka No. 1, indicate significant potential for these porous units as a reservoir in suitable structural traps.

BASE METALS (by P.M. Green, P.E. Balfe)

Geochemical analyses from GSQ Mount Whelan 2 show that one sample from the basal part of the Thorntonia Limestone contains highly anomalous concentrations of lead (1100 ppm) and zinc (780 ppm). Crystalline sphalerite was noted in the Ninmaroo Formation, in the lower and middle units of the Kelly Creek Formation, and in the limestone unit of the Nora Formation. Both the Ninmaroo and the Kelly Creek Formations may have been suitable host rocks for Mississippi Valley type lead-zinc mineralisation.

MAPS

During the year the 1:100 000-scale preliminary geological maps of MOUNT WHELAN (produced by GSQ), TOKO, and ABUDDA LAKES (produced by BMR) were published. These, together with the previously published southern Burke River Structural Belt, and Adam Special completed the five 1:100 000 map sheets proposed in the first phase. It is anticipated that the above-named sheets, with some additional data from MOUNT BARRINGTON, will be reduced and compiled into a 1:250 000 scale special sheet.

GLENORMISTON AEROMAGNETIC INTERPRETATION

by

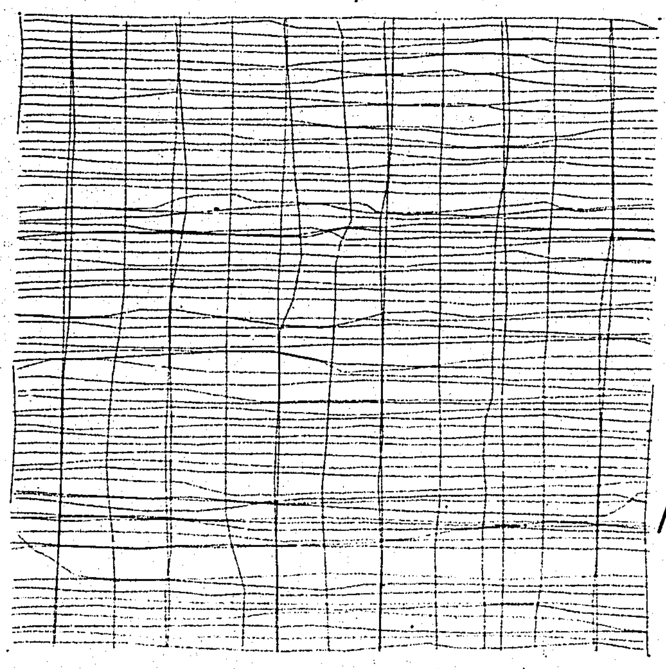
J. Rees

Study of the detailed aeromagnetic data flown by BMR in 1977 in the Glenormiston area continued as time permitted during the year. Further data processing was completed, to enhance magnetic features and prepare data for release through the Government Printer (Fig. D4).

Interpretation to date has assumed a simple model with Palaeozoic (with or without Adelaidean) sediments overlying pre-Palaeozoic (?Arunta-type) basement in the west and shallower Mount Isa-type rocks as basement in the east.

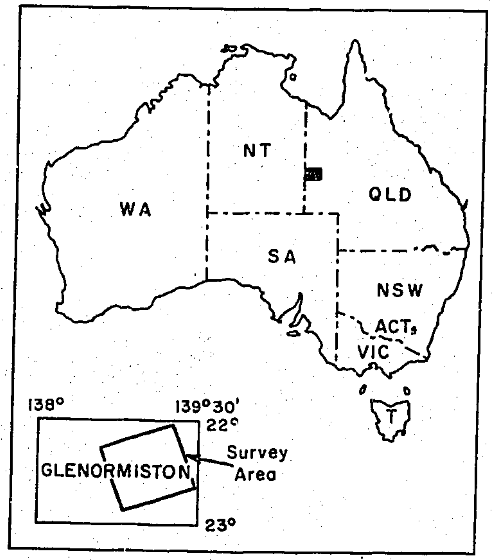
Northerly trending magnetic features in the centre and east of the area exhibit a high degree of correlation with trends in the Mount Isa block and probably correspond to susceptibility contrasts within the basement. Some fold structures are also evident.

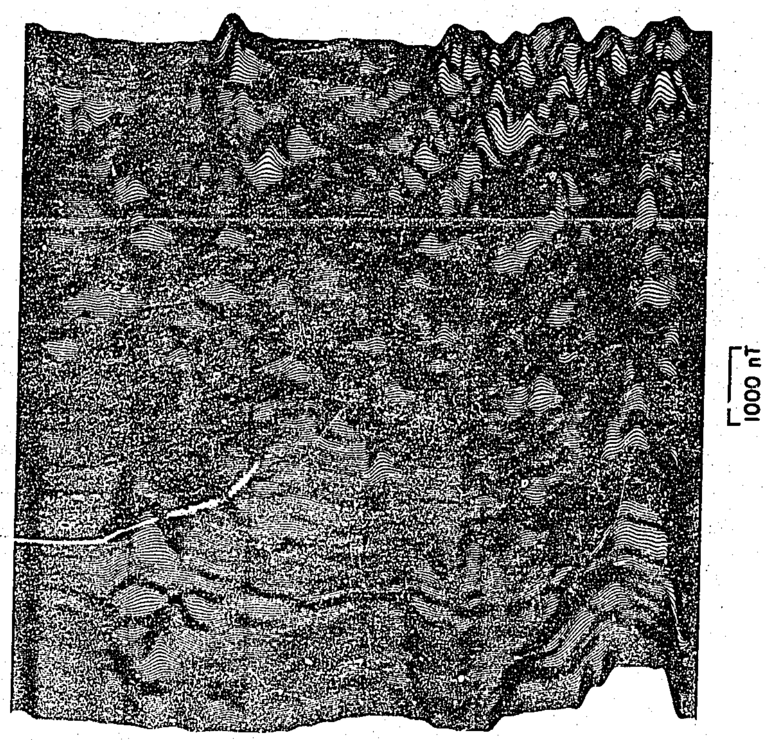
Less obvious northwest magnetic trends in the centre and west of the area are probably caused by basement faulting. There is no evidence from the magnetics to confirm a significant susceptibility contrast between basement rocks in the east and west of the area.



Flight path

TMI contours
(10 nT)





TMI profiles

0 50 km

Report 230

F54/B1-146-1A

Fig. D4 Glenormiston aeromagnetics; magnetic contours, flight path, stacked profiles.

Magnetic modelling has suggested a susceptibility contrast of 0.001-0.003 between basement and sediments with thicknesses of 300-400 m in the northwest and central areas, 100-200 m in the northeast and 200-1000 m in the southwest. Contacts dip fairly steeply to the west. The more prominent magnetic anomalies in the northwest and southwest of the area may be caused by granite intrusions and/or local basement relief.

Palaeozoic sediments thicken in the centre and south of the area, and a closed ?basin structure in the centre is defined by prominent north-south trends truncated to the north and south by northwest faulting.

CENTRAL EROMANGA BASIN PROJECT

Compiled by

F.J. Moss, Project Co-ordinator

Regional multidisciplinary geoscientific investigations in the central Eromanga Basin area (Fig. D5), which were outlined in BMR Record 1980/32 by P.L. Harrison & others, commenced early in 1980. The main objective of the project is to determine the petroleum resource potential of the area and assist in efficient and comprehensive petroleum exploration.

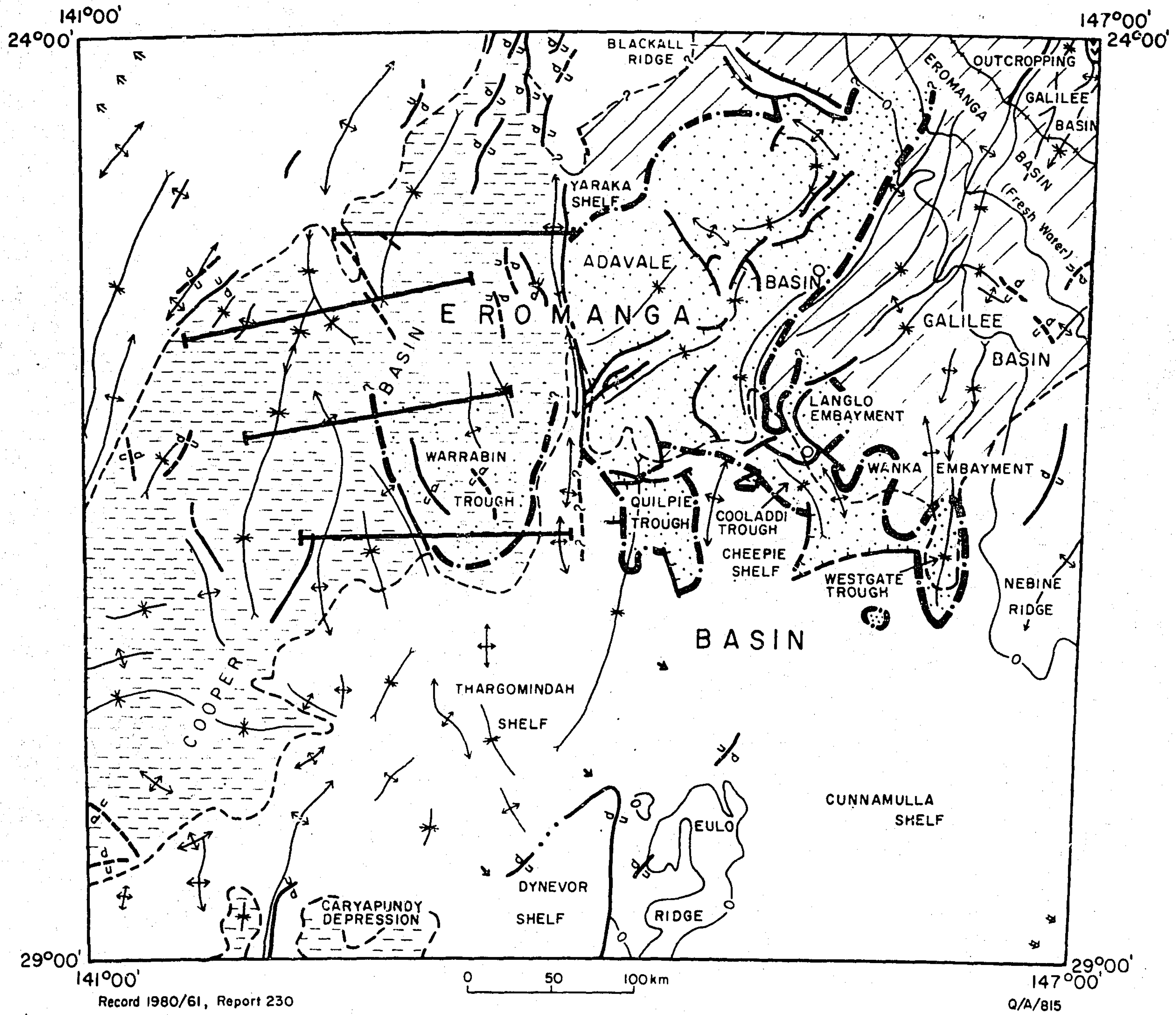
Information is being obtained on the regional structural, depositional, and thermal histories of the area from 24° to 29°S and from 141° to 147°E. The principal area where surveys and studies were concentrated in 1980 is from 25° to 27°S and from 141° to 144°E lying mainly west of the Canaway Fault.

During the period January to June 1980 the main activities were the review of existing geoscientific information, background research into techniques applicable to studies of the area, and preparation for surveys west of the Canaway Fault. These activities are described in BMR Record 1980/60 by F.J. Moss. The following contribution provides more details on the work undertaken, particularly in the July to October period.

The processing, analysis, and interpretation of the data are at an early stage, and further work will be required to assist in determining the petroleum prospects of the area.

PETROLEUM SOURCE ROCK STUDIES (B.R. Senior)

The maturity and petroleum source rock potential of the Eromanga Basin sequence was reported by Senior [illegible]ermehl (1980) in the BMR Journal vol. 5. This work demonstrated that most of the Jurassic and some of the deeply buried



Cooper Basin

Adavale Basin (overlain by Galilee)

Galilee Basin

Outcropping Drummond Basin

Outcrop margin of Eromanga Basin

Zero structure contour on base of Rolling Downs Group (datum M.S.L.)

Anticline axis with plunge direction

Syncline axis with plunge direction

Monocline

Fault cutting Eromanga Basin and older rocks

Thinning of Eromanga Basin rocks towards the Boulia Shelf

Proposed 1980 seismic traverses (generalised)

Thinning of Eromanga Basin rocks towards Dynevor, Cunnamulla Shelves and Eulo Ridge

Thickening of Eromanga Basin rocks towards the Surat Basin

Concealed truncated margin of Permo-Triassic Cooper and Galilee Basins

Fault cutting pre-Eromanga Basin rocks

Margin of Adavale Basin and equivalents

Fault cutting Adavale Basin rocks

Salt diapir in Adavale Basin rocks

Fig. D5 Structural sketch map, central Eromanga Basin

Cretaceous rocks have generated hydrocarbons from relatively abundant source rocks. These studies were expanded during the year to evaluate critical sections within individual petroleum exploration wells. Drill cuttings were selected at 10 m intervals from Galway 1, Bodalla 1, and Durham Downs 1, and are being analysed using the 'rock eval' pyrolysis technique. Results are not yet available, but visual examination indicates good source rocks in the Thomson Syncline area, where dark organic lutites are present in the Jurassic sequence in Galway 1.

HYDROGEOLOGY (M.A. Habermehl) - see also Report of Sedimentary Section

As part of the project a review is to be carried out of the hydrogeological data of the multilayered confined aquifer system in the area, and assess the results of the mathematical computer-based model which simulated the groundwater hydrodynamics in the Great Artesian Basin (Fig. S4).

Isotope hydrology and hydrochemistry studies are part of the investigations, and provide both information complementary to data obtained by conventional hydrological techniques and an independent check on derived hydraulic data. They also provide additional information on rates of flow, flow patterns, and the possible transport of minerals and hydrocarbons.

As part of the hydrochemical study, forty-eight flowing artesian water wells in fourteen 1:250 000 Sheet areas located between 24° and 26°S, and 140° and 143°E were sampled during a field trip in September 1980. All wells were sampled for chemical analyses and possible hydrocarbon content of the artesian groundwater; six selected wells were sampled with specially designed sampling tubes to obtain sealed throughflow grab samples, and ten selected wells were sampled for environmental isotope analyses ($\delta^{13}C$), the analyses to be carried out by AAEC.

Results from the analyses of the samples might assist in the studies of possible hydrocarbon migration and stagnation near structural and stratigraphic traps in the area west of the Canaway Fault, and define the hydrodynamic and hydrochemical character of the area, and could lead to further research and/or methods to aid hydrocarbon exploration.

LITHOLOGY STUDIES (V. Passmore, W.Z. Hessler)

Little lithological work was undertaken owing to previous commitments of the geological staff. A north-south lithological correlation cross-section across the Narrabin Trough was prepared in order to show facies changes and formation thickness as a guide to recognising seismic reflectors west of the Canaway Ridge. Two other cross-sections are planned through wells in the northern Cooper Basin.

Identification of seismic reflectors and interpretation of environments of deposition from this year's seismic results in the study area is in progress.

SEISMIC REFLECTION STUDIES (J. Pinchin, A.R. Fraser, S.P. Mathur, P.L. Harrison (Alliance Oil Development), B.R. Senior, K. Wake-Dyster, M. Sexton, D. Pfister, F.J. Moss)

A brief selective review of existing seismic data was made to assist in planning the 1980 BMR seismic survey in the area west of the Canaway Fault. Good-quality seismic cross-sections were used, ties were made to wells in the southwest of the survey area, and interpretative line sketches were drawn along key sections. Seismic reflection traverses recorded by BMR in the area during the period July-November are shown in Figure D6.

The data currently being processed indicate generally high-quality sections. Traverse 1 is the only section presently available for interpretation (Fig. D7). This traverse crosses the Warrabin Trough and reveals 3000 m of Devonian sedimentary rocks in a fault-bounded trough below the Cooper sequence. This trough had been recognised on previous seismic sections, but little detail was available on its nature and likely stratigraphy. Traverse 1 shows a previously unknown eastern shoreline to the trough; this raises questions of the palaeogeography of the area in Devonian times, the likely connection to the Adavale Basin, and the possibility of marginal marine, reefal, or deltaic facies providing targets for petroleum exploration.

An interpretation of the seismic stratigraphy along traverse 1 also reveals the onlap edge of the Permian coal measures, and planar cross-bedding within the Triassic Nappameri Formation, which may indicate a high-energy sandy facies within this unit. This could also provide an attractive petroleum exploration target.

Several seismic sections from previous surveys have been reprocessed. The data were transcribed from analogue to digital form at BMR and sent to a contractor for processing. All have shown considerable improvement, and more will be treated in this way.

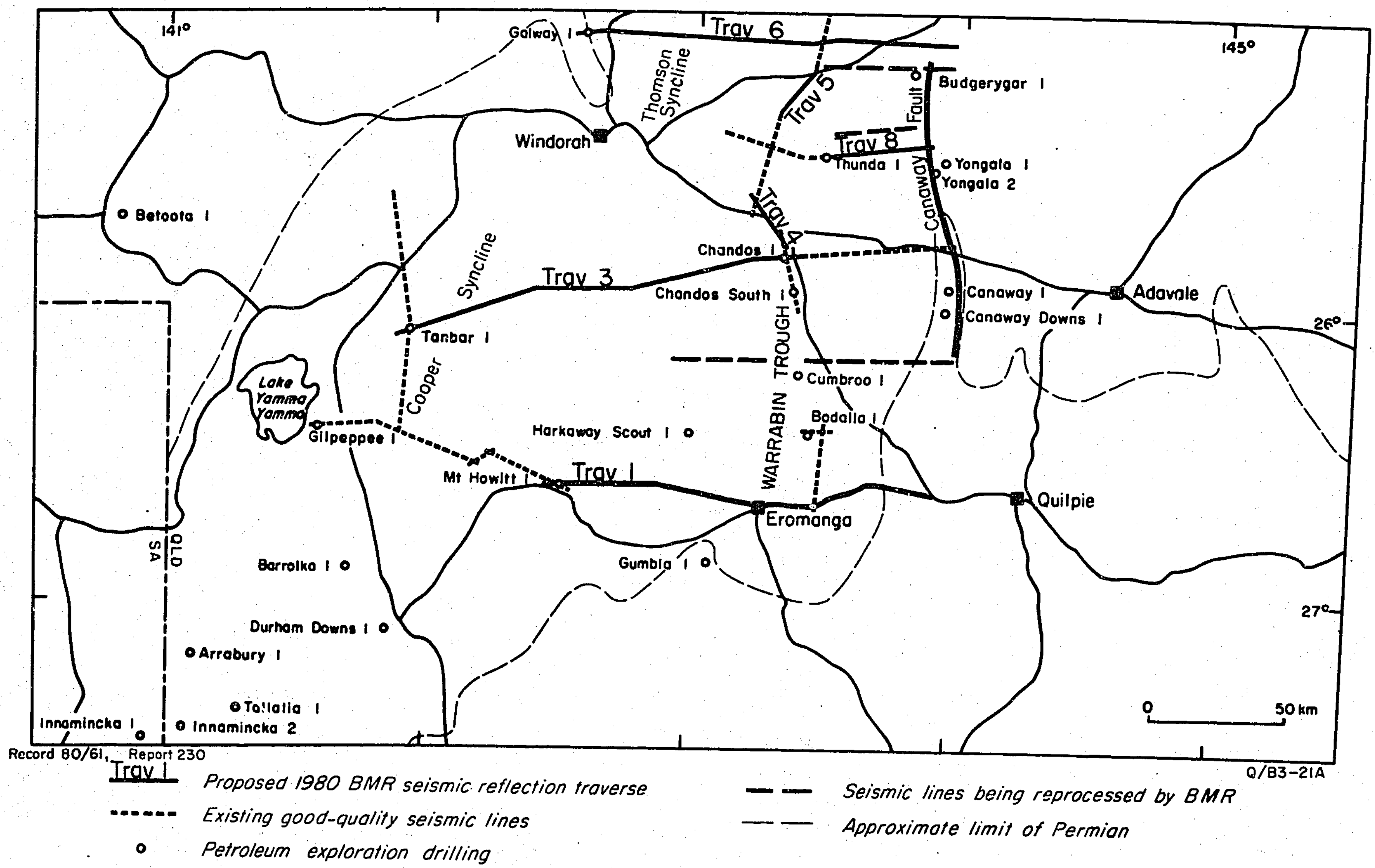


Fig. D6 Seismic reflection and gravity traverses, 1980, central Eromanga Basin

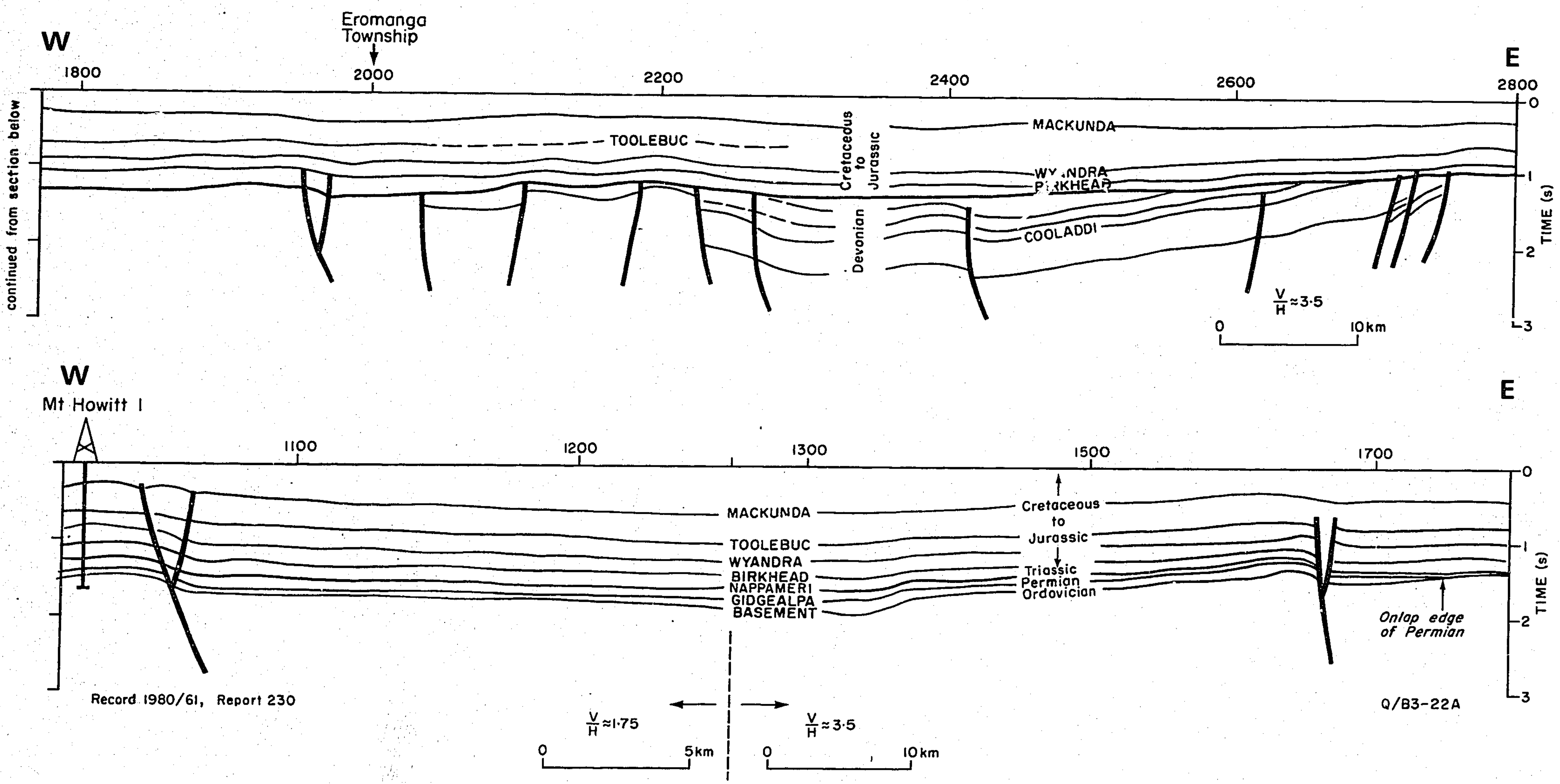


Fig. D7 Sketch of seismic section for traverse I, central Eromanga Basin. See Fig. D6 for location

The regional traverses recorded by BMR in 1980 will enable some of the earlier subsidised seismic lines to be reinterpreted. A computerised data bank of shot-point locations has been produced, and interpreted seismic horizons will be digitised, to support the computer plotting of regional structure and isopach maps.

Wide-angle reflection recordings made along traverse 1 in conjunction with refraction recordings are being analysed to provide vertical velocity information in the crust. The vertical reflection recordings made to 20 s on all traverses will be analysed to assist in determining the deep crustal structure of the area.

GRAVITY INVESTIGATIONS (W. Anfiloff, K.L. Lockwood)

Bouguer gravity anomaly contour maps were produced for the area west of the Canaway Fault, covering the Canterbury, Windorah, Barrolka, and Eromanga 1:250 000 Sheet areas (Fig. D8). The data were obtained from the BMR gravity data bank used to compute the Gravity Map of Australia.

The correlation between regional gravity and structural features is generally fair throughout the area.

During the period July to November 1980, gravity measurements were made along the 1980 BMR regional seismic traverses (Fig. D6) and some company traverses, at 500 m intervals. The detailed information along the regional lines surveyed mainly perpendicular to the strike of the faults and main structural features will be used in deriving models to assist in resolving the regional structural picture.

DEEP CRUSTAL SEISMIC INVESTIGATIONS (D.M. Finlayson, C.D.N. Collins, J. Lock, C. Rockford)

Long-range seismic refraction recordings were made to determine the deep crustal structure and the velocity deep profile of the basement beneath the basins in the central Eromanga Basin area. Recordings were made along a 300 km east-west traverse (Fig. D9) crossing the Quilpie Trough, Canaway Ridge, Warrabin Trough, and part of the Cooper Syncline.

The refraction recording was divided into two phases. The first comprised refraction recording along the 150 km section of the traverse covered by deep crustal vertical and wide-angle seismic reflection recording. This 150 km traverse was divided into four 37.5 km traverses placed end to end. Two-

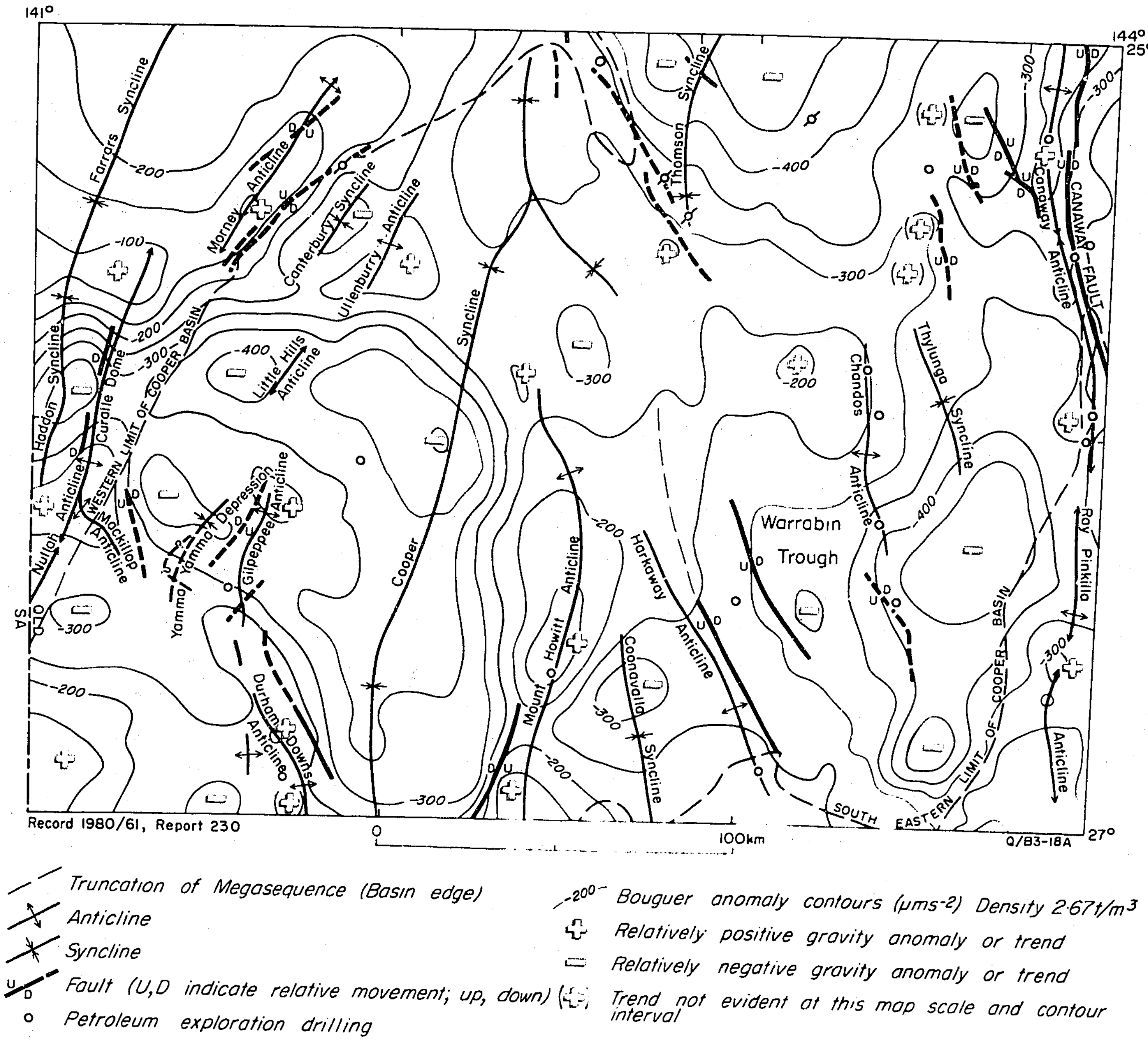


Fig. D8 Bouguer anomalies and structural features, central Eromanga Basin

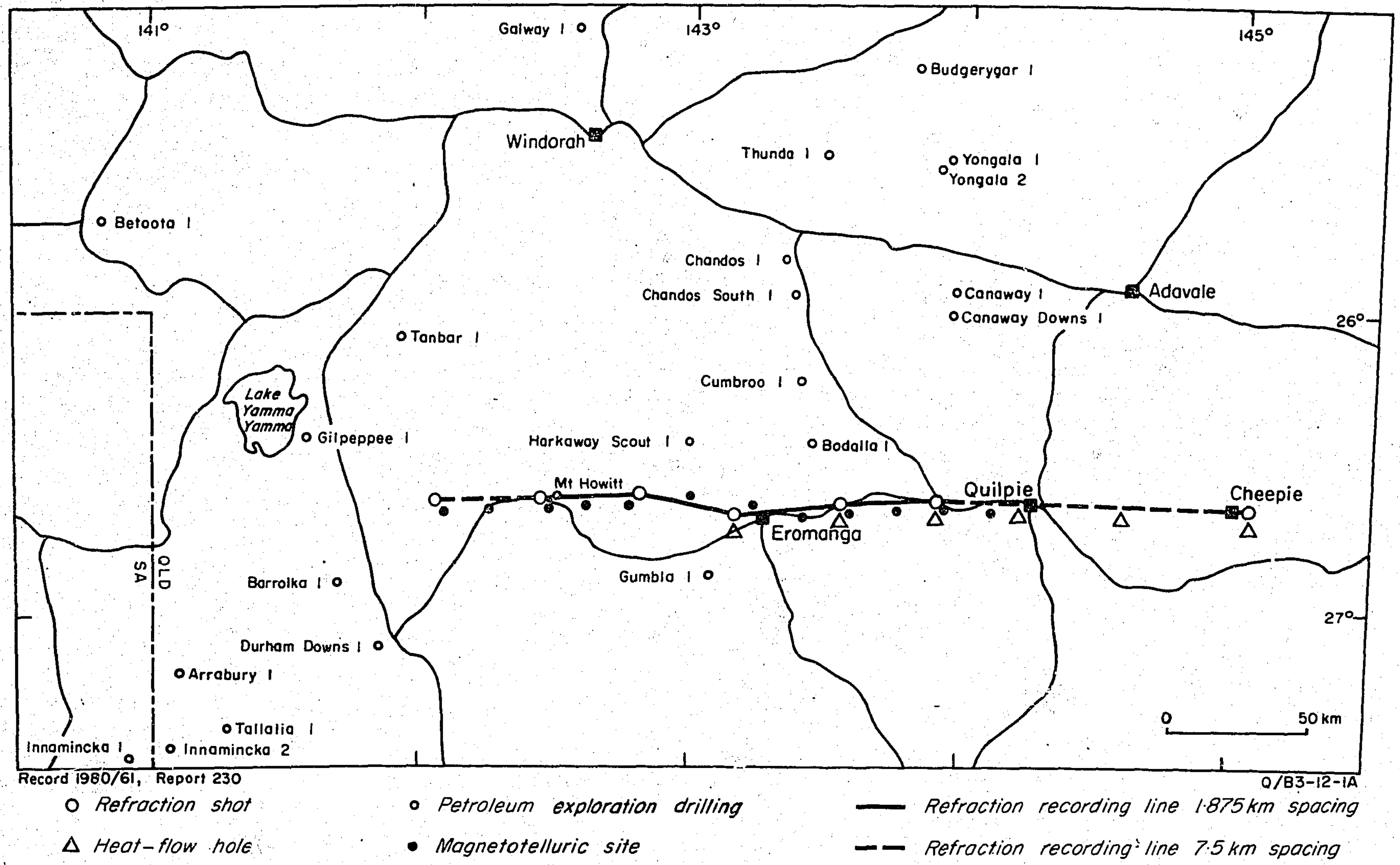


Fig. D9 Locations of seismic refraction shot-points, heat-flow holes, and magnetotelluric sites, 1980, central Eromanga Basin

hundred kilogram shots were fired at the ends of each traverse, and a 400 kg shot was fired 37.5 km from each end. Analog recordings were made at 21 stations, 1.875 km apart along each traverse. This effectively provided four adjacent reversed traverses each of 37.5 km and three overlapping reversed traverses 75 km long, all recorded at 1.875 km spacing.

The second phase comprised recording on a 300 km traverse along which heat-flow and magnetotelluric measurements were also made. Recording was along two 150 km traverses, end to end, designed to record arrivals from refractors down to and including the upper mantle. Seven-hundred-and-fifty kilogram shots were fired at the ends of each traverse, and a 2500 kg shot was fired at a distance of 150 kg from one end of the traverse. Analog recordings were made at 41 stations with a station interval of 7.5 km. This effectively provided a reversed traverse of 300 km and within this traverse two adjacent reversed traverses 150 km long, all recorded at 7.5 km station spacing.

Latitude and longitude of shot-points and station sites for the extreme eastern and western ends of the line (shown as dotted lines in Fig. D9) were determined from locations marked on ortho-photomaps of the region. Those for the surveyed central section of the line (shown as a solid line in Fig. D9) were calculated from AMG co-ordinates. The analog recordings from 20 shots at 101 station sites recorded by 21 instruments are being processed digitally for the compilation of seismic record sections which will be interpreted to infer the seismic velocity/depth profile of the basin.

HEAT-FLOW MEASUREMENTS (D.M. Finlayson, J. Lock, J. Williams, J.P. Cull, A.G. Spence)

Heat-flow measurements were made at six sites with 40 km spacing in a profile generally coinciding with part of the magnetotelluric profile and the seismic refraction line (Fig. D9). Probes were designed to indicate geothermal gradients at a depth of 100 m. Data obtained at such depths are subject to climatic perturbations (BMR Record 1979/55) and there are considerable difficulties in specifying absolute values of heat flow. However, the magnitude of any correction should be similar for all sites, and consequently it is possible that relative values of heat flow can be determined. Any trend or anomaly associated with basin structure may then be used to construct detailed models of thermal history related to depositional rates.

The probe components were housed in 4 m lengths of plastic tubing normally used as electrical conduit. Three thermistors, spaced 2 m apart, were sealed in each probe and were monitored using 110 m of twin-core cable. A lead ballast was used to aid emplacement. Before assembly the thermistors were calibrated against a ˡᵃtinum resistance thermometer standard, and the completed probes were tested ıepth of 100 m in a drillhole 200 m southeast of the BMR building in Canberra.

Geothermal gradients in the Eromanga Basin were measured soon after each hole was completed. The probes were then left in place and the readings were repeated after a further delay of not less than two weeks. A drift was observed consistent with the decay of thermal transients associated with drilling. However, some spurious values were noted, and probe failure is indicated for at least one site. All probes have been retrieved, and each thermistor will be recalibrated for greater accuracy. Values of heat flow will then be calculated, combining geothermal gradients with thermal conductivity data from identical depths; a 3.1 m bottom core was taken in each hole for this purpose.

MAGNETOTELLURIC (MT) INVESTIGATIONS (A.G. Spence, J. Whatman)

MT records were obtained in the period August-October at 12 sites with 20 km spacing in a profile west of Quilpie (Fig. D9). Seismic reflection, seismic refraction, and relative heat-flow data have also been obtained on the MT line from the Cooper Basin to the margin of the Adavale Basin. As a result, the resolving power of MT in this area can be readily established.

Satisfactory recordings were obtained at all sites, but the initial quality was affected by intermittent faults on one E channel. Consequently the duration of the survey was extended to allow time for major repairs on the disc servo assembly. No inversions have been attempted since the data must first be screened for cross-over errors. However, the data are internally consistent and, since orthogonal components are generally coincident, major features may therefore be resolved with one-dimensional analysis alone.

Some divergence in plots of apparent resistivity has been noted at periods less than 1 Hz for sites near Eromanga; therefore, some structure in the near-surface sedimentary sequence may be detectable by MT. Experience in the Cooper Basin (Moore & others, 1977; BMR Record 1977/41) had suggested that because of a lack of resistivity contrasts only the base of the Cretaceous would be resolved. At the other extreme it is probable that there is a major conductivity change at depths of about 90 km.

After filtering, the MT data obtained in 1980 will be integrated with other geophysical information along the same profile, in order to determine the dimensional parameters associated with each unit; these parameters will help to elucidate the structural and depositional history of the area.

ELECTRICAL AND ELECTROMAGNETIC INVESTIGATIONS (J.A. Major)

The January-June progress report (BMR Record 1980/60) outlined the objectives, techniques, limitations, and survey design philosophy associated with the application of electrical methods to a study of the Eromanga Basin. After submitting that report, forward models were run of the DC resistivity response of the geoelectric sections derived from the Mount Howitt 1 and Bodalla 1 well logs. The results showed that DC resistivity would not be a practical method to investigate the low-resistivity (1-3 Ωm) sediments to depths in excess of 1 km. Electromagnetic-sounding techniques may still be viable, but no modelling has yet been done. The future of this project will depend on the results of the current MT work and the analysis of further electrical well logs.

GROUND MAGNETICS (J.A. Major, R. Curtis)

A boom was constructed to carry the magnetic sensor behind a Land Rover. The original Geometrics G803 proton magnetometer on loan from the Airborne Subsection was required for aeromagnetic work, and a prototype G803 magnetometer now installed in the vehicle was found to be unreliable. Frequent breakdowns with the digital acquisition system result in the system as a whole being presently unsatisfactory for field use. When a reliable system is available, total magnetics can be read along the 1980 BMR seismic traverses in the Eromanga Basin in two weeks.

AEROMAGNETIC REVIEW (J. Rees, K. Horsfall, S. Wilcox)

The results of aeromagnetic surveys over the central Eromanga Basin area were reviewed to determine the availability and quality of the data and to assess the existing interpretations.

Ten aeromagnetic surveys provide poor to fair coverage over most of the area except in the southeast over the Cunnamulla Shelf (Fig. D10). A composite total magnetic intensity contour map has been compiled at 1:1 000 000 scale (Fig. D11). Only 35% of original data is available to BMR and only 50% of this is in a digital form.

Examination of original data and review of the results of previous surveys suggest that further systematic processing of existing data is warranted.

Additional surveying has been recommended (Fig. D12). An orientation survey proposed for 1981 will provide interpretation control along seismic traverses in the Cooper Basin area and attempt to resolve the structure of the Canaway Ridge. A high-resolution (0.1 nT) magnetometer will be used to improve the definition of 1-5 nT anomalies which were not resolved in previous surveys but are considered of fundamental significance for aeromagnetics to contribute to the mapping of the Eromanga Basin.

The results of the orientation survey will be used to define the requirements for further systematic airborne surveying.

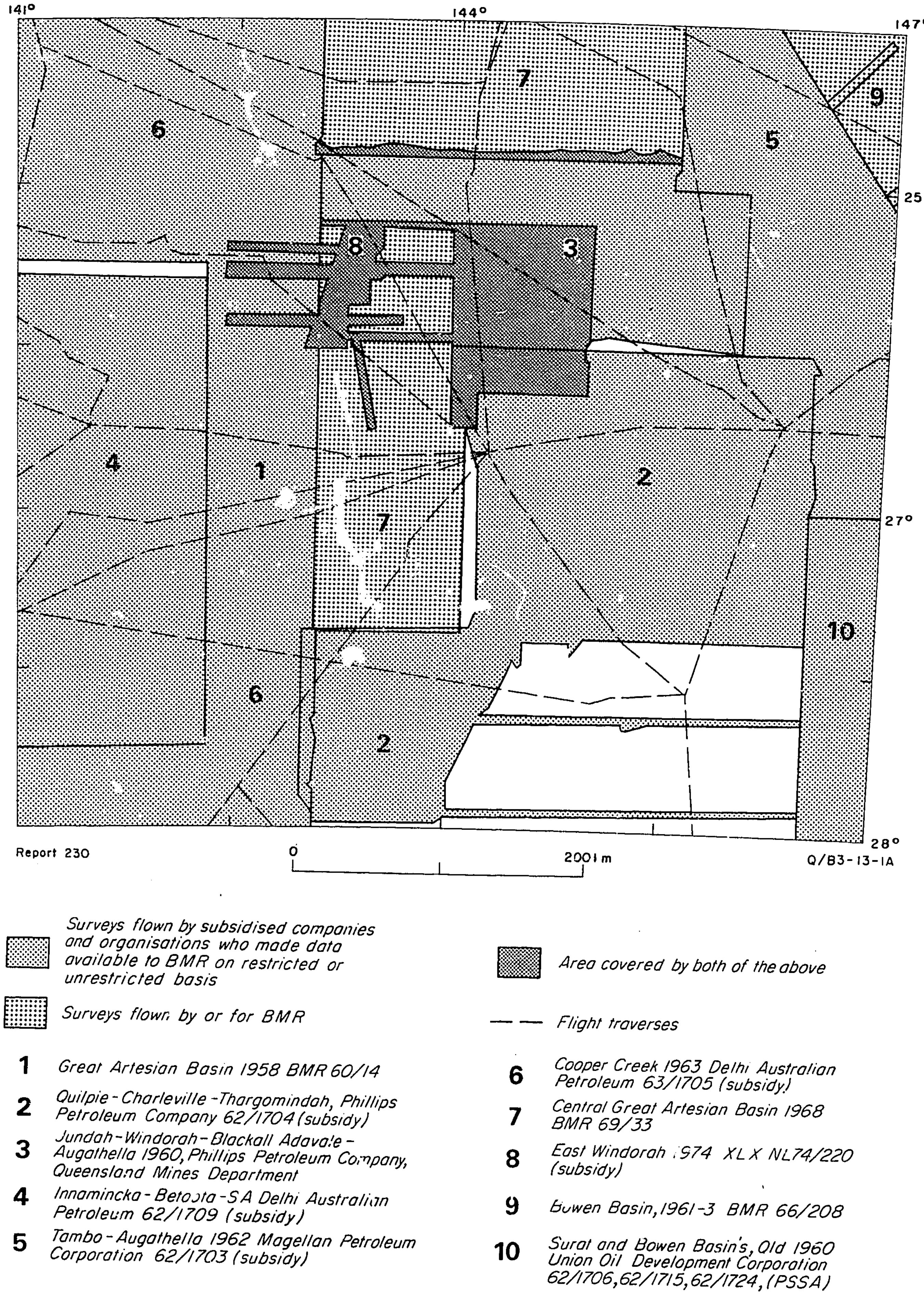


Fig. D10 Existing aeromagnetic coverage, central Eromanga Basin

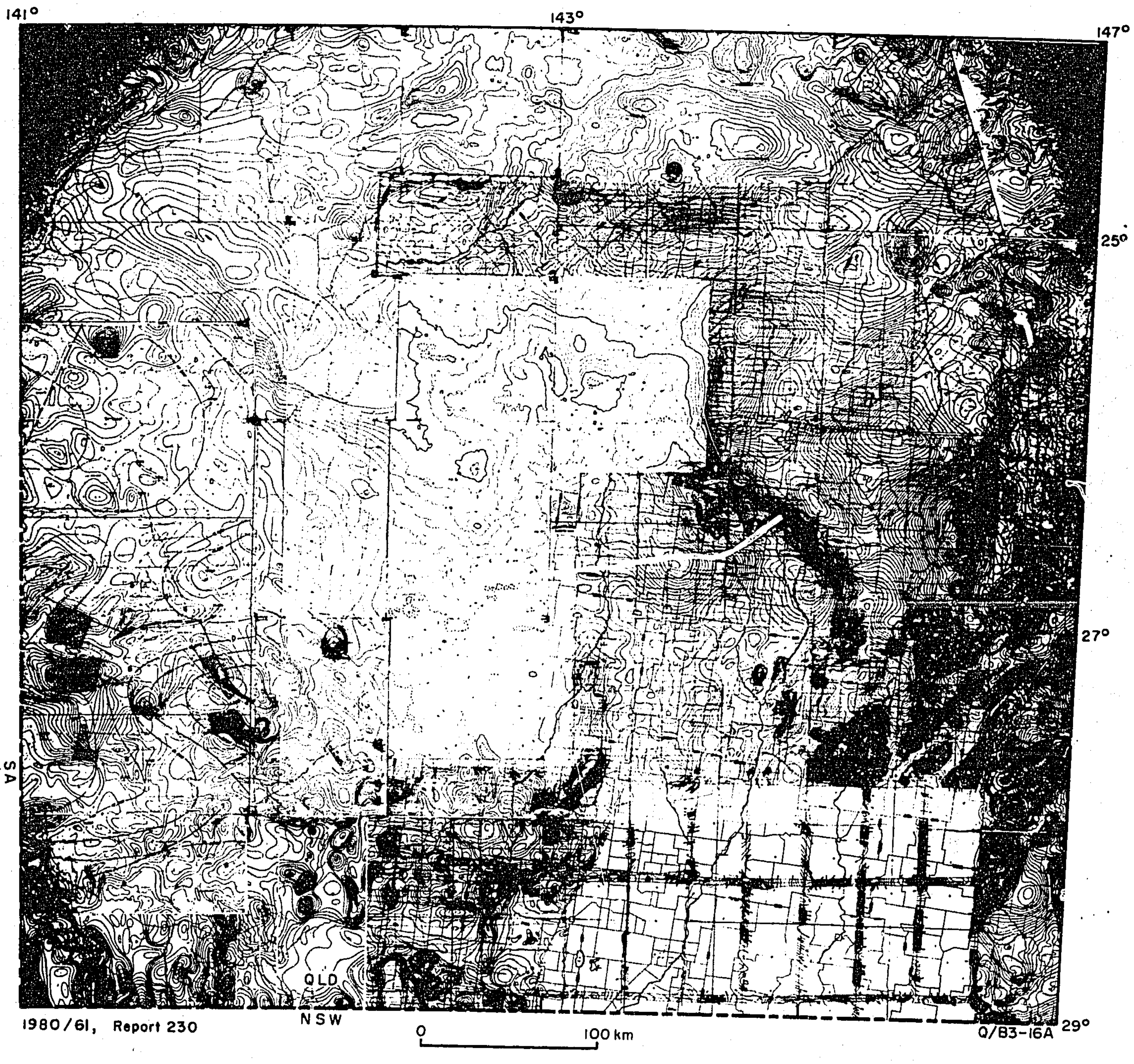
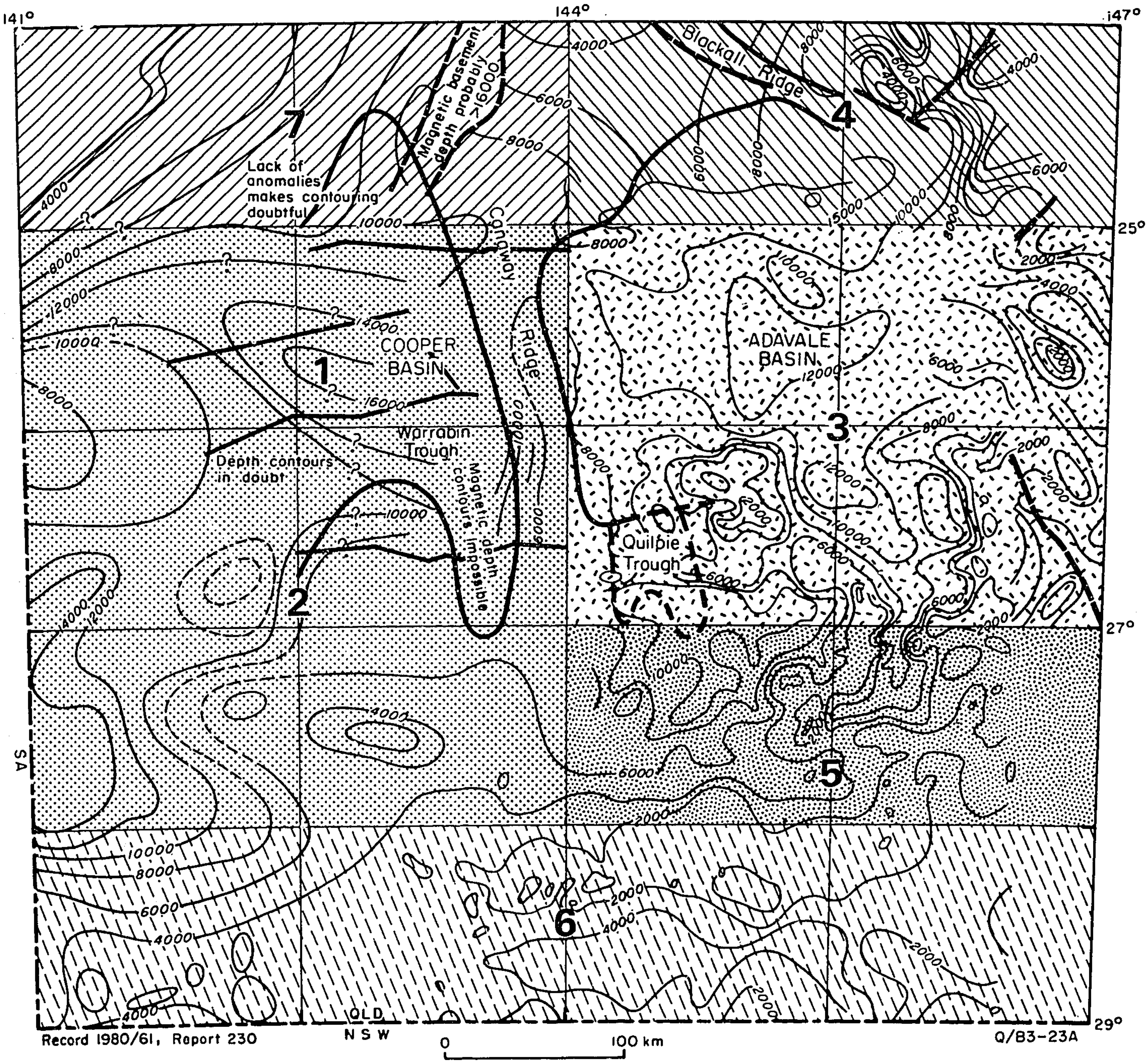


Fig. D11 Aeromagnetic contours, central Eromanga Basin



Depth to magnetic basement compiled from individual survey reports (feet below M.S.L.) (2000)

Basin boundaries (from BMR Record 1969/33, plate 7)

Fault or magnetic depth discontinuity

1 *BMR seismic traverses 1981*

2–7 *Areas in order of priority*

Fig. D12 Aeromagnetic survey results and priorities, central Eromanga Basin

BAAS BECKING GEOBIOLOGICAL LABORATORY

SEDIMENTOLOGICAL STUDIES IN SPENCER GULF

by

R.V. Burne

STAFF: R.V. Burne, J.B. Colwell, L. Pain, M.H. Tratt.

The program seeks to establish the sedimentological framework for associated microbiological and geochemical studies, and to provide a model for the palaeogeographical interpretation of appropriate orebody host rocks.

In the past year the environmental distribution, sediment facies, and evolutionary history of prograding coastal complexes near Fisherman Bay, Mambray Creek, Redcliff Point, and Wood Point (Fig. B1) were studied; the diagenesis of marine carbonates and the evolution of an association of megapolygons and teepees around groundwater springs at Fisherman Bay were described; and the implications of the skeletal carbonate component distribution of Spencer Gulf sediments for the understanding of the environmental controls governing the extent of various carbonate provinces were considered.

The distribution of environments of the Redcliff complex (Fig. B2) illustrates well the distinction between exposed (windward) and protected (leeward) environmental zonation found to some degree in all the coastal complexes. Comparison of tidal inundation data and relative elevation to comparable environments in representative transects across all the study areas confirm that blue-green algal mat colonisation occurs at similar elevation on both windward and leeward shorelines (Fig. B3). Comparison of these data with those on the environments shown in Figure B2 indicated that the Redcliff complex is in fact dominated by intertidal environments.

Both windward and leeward shorelines are prograding in the coastal complexes; this appears to be due to both the accumulation of sediment carried shorewards by waves and tidal currents and to relative sea-level fall during the past 5000 years. Indicators of relative sea level such as the beach ridges, mangrove stands, and beach rock are not very precise markers in areas of large tidal variation, such as northern Spencer Gulf. However, the subtidal sea-grass meadows give rise to a distinctive sedimentary facies which is readily recognised in core material. It is typically a grey, poorly sorted, carbonate sand with abundant fibres and root sheaths of sea-grass. The top of this facies in cores from the intertidal and supratidal zone, therefore, provides a reliable indicator of the maximum height of the low tide level in the area. Figure B4 shows a transect near Wood Point where depth of the top of the sea-grass facies

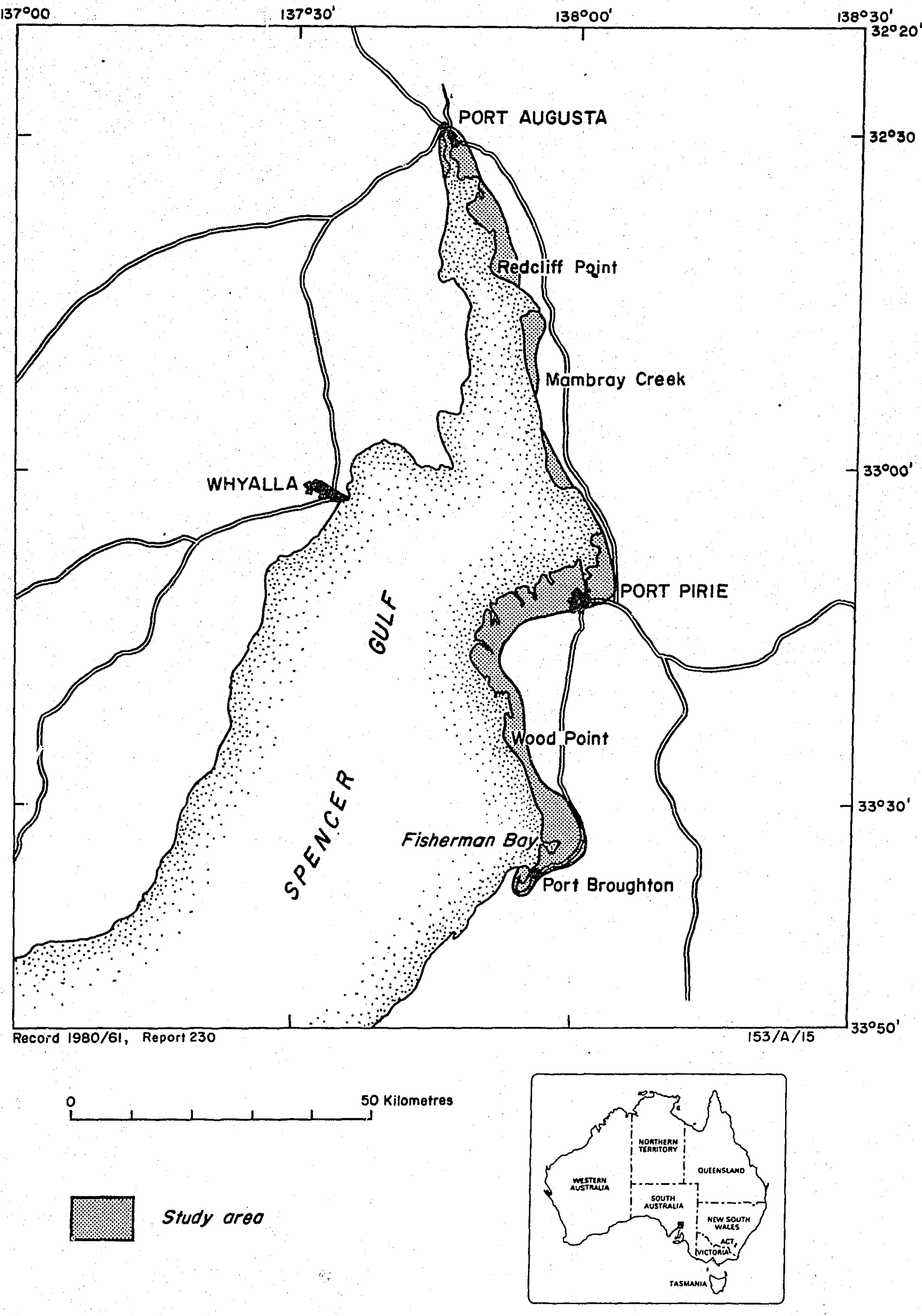


Fig. B1 Location of Spencer Gulf study areas

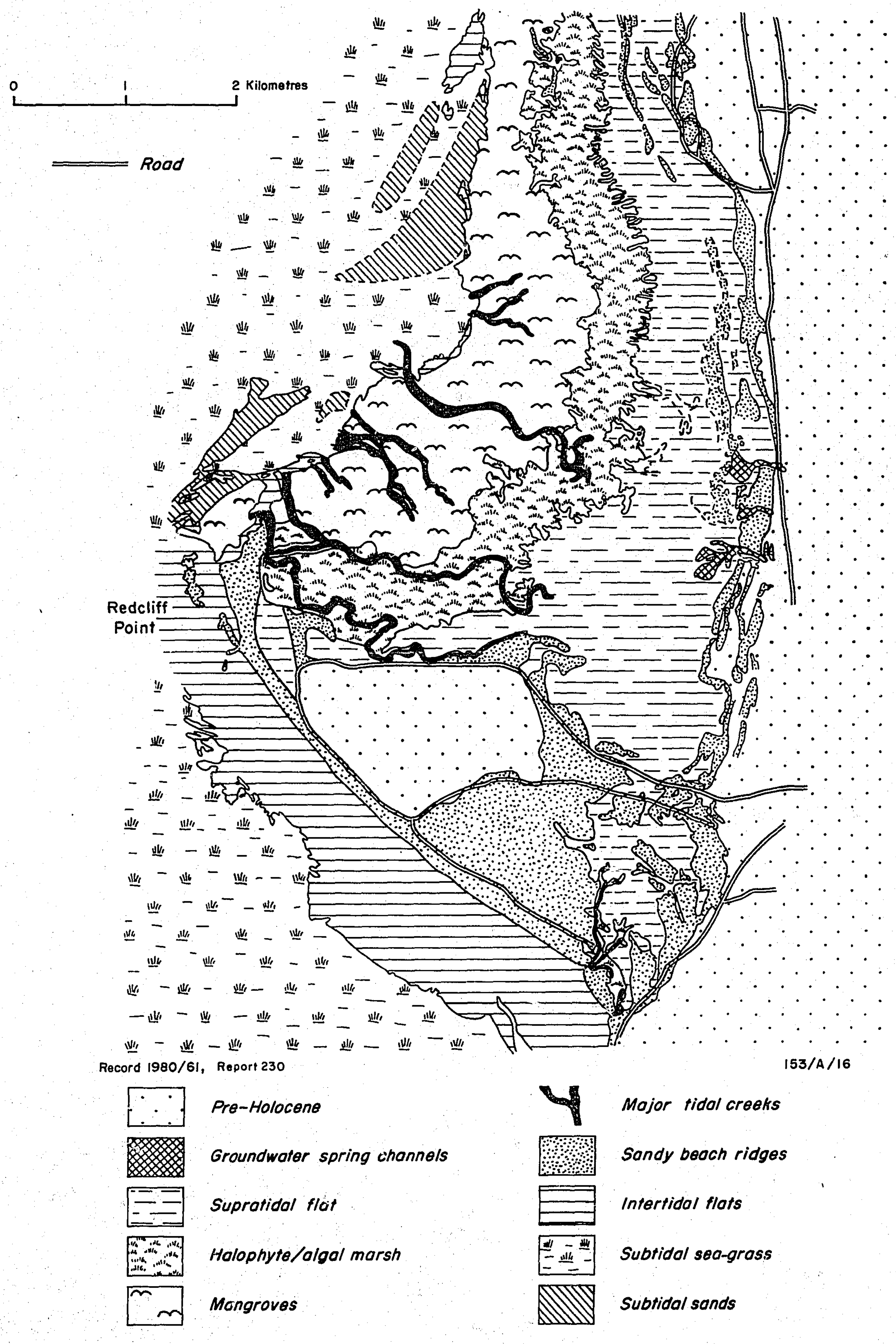


Fig. B2 Environment zonation of the Redcliff Complex

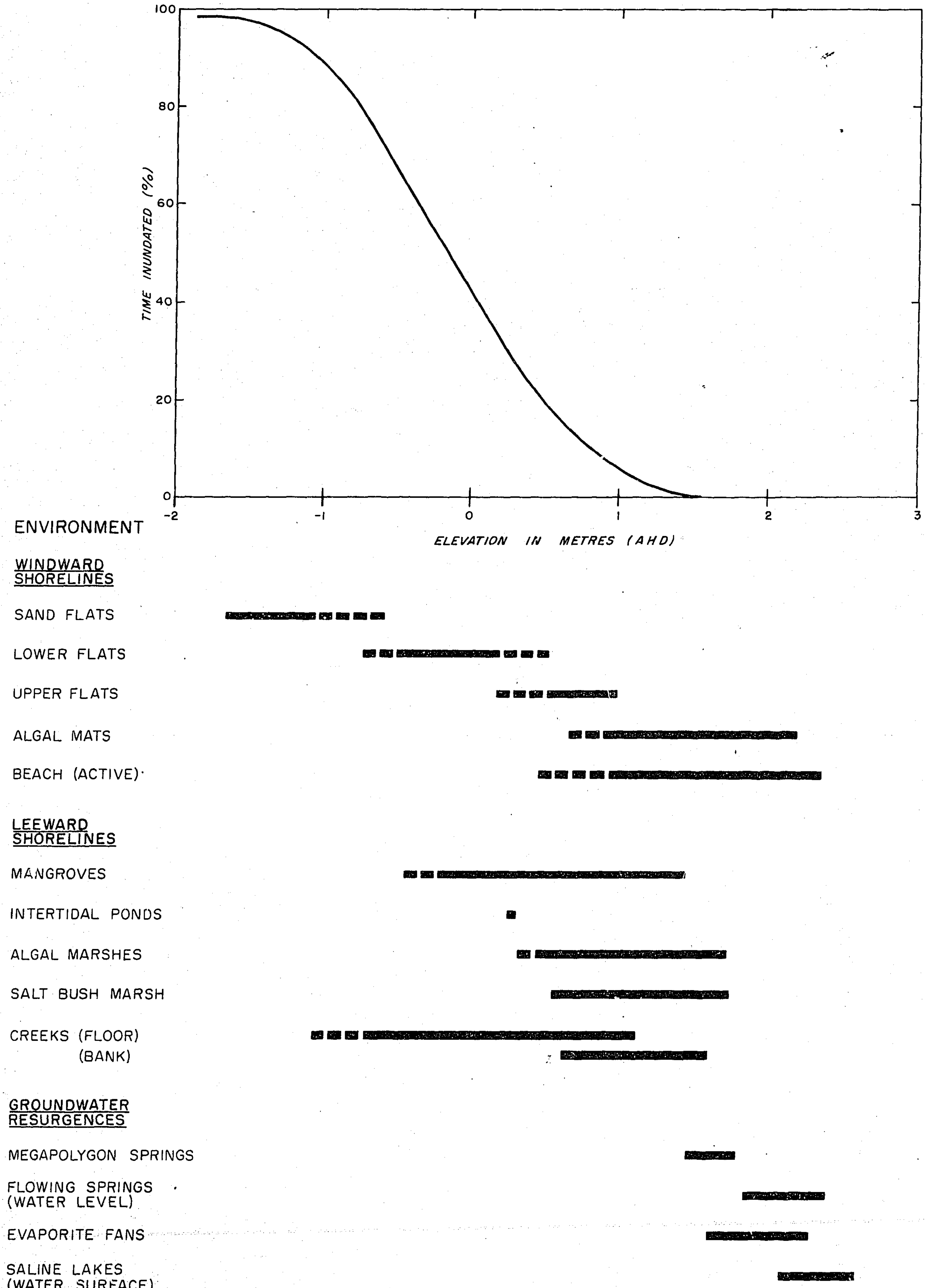


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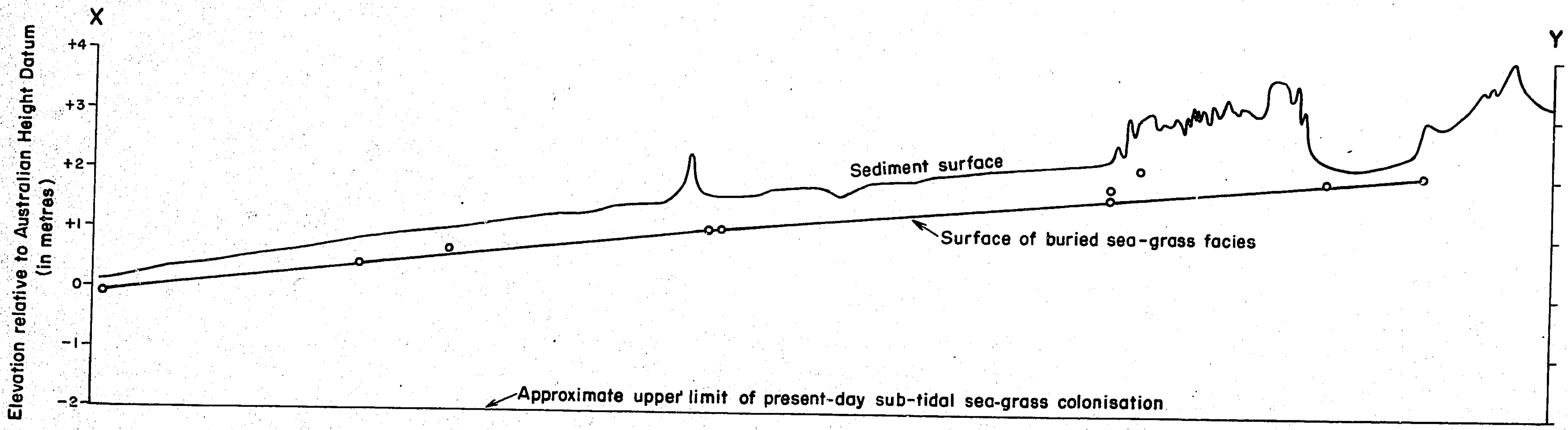
Fig. B3 Relationship between tidal inundation and environmental zonation of coastal complexes



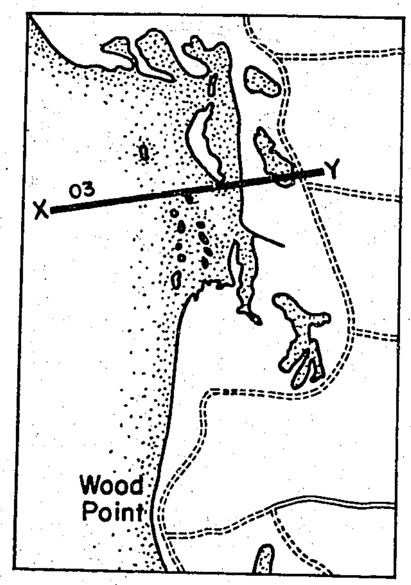
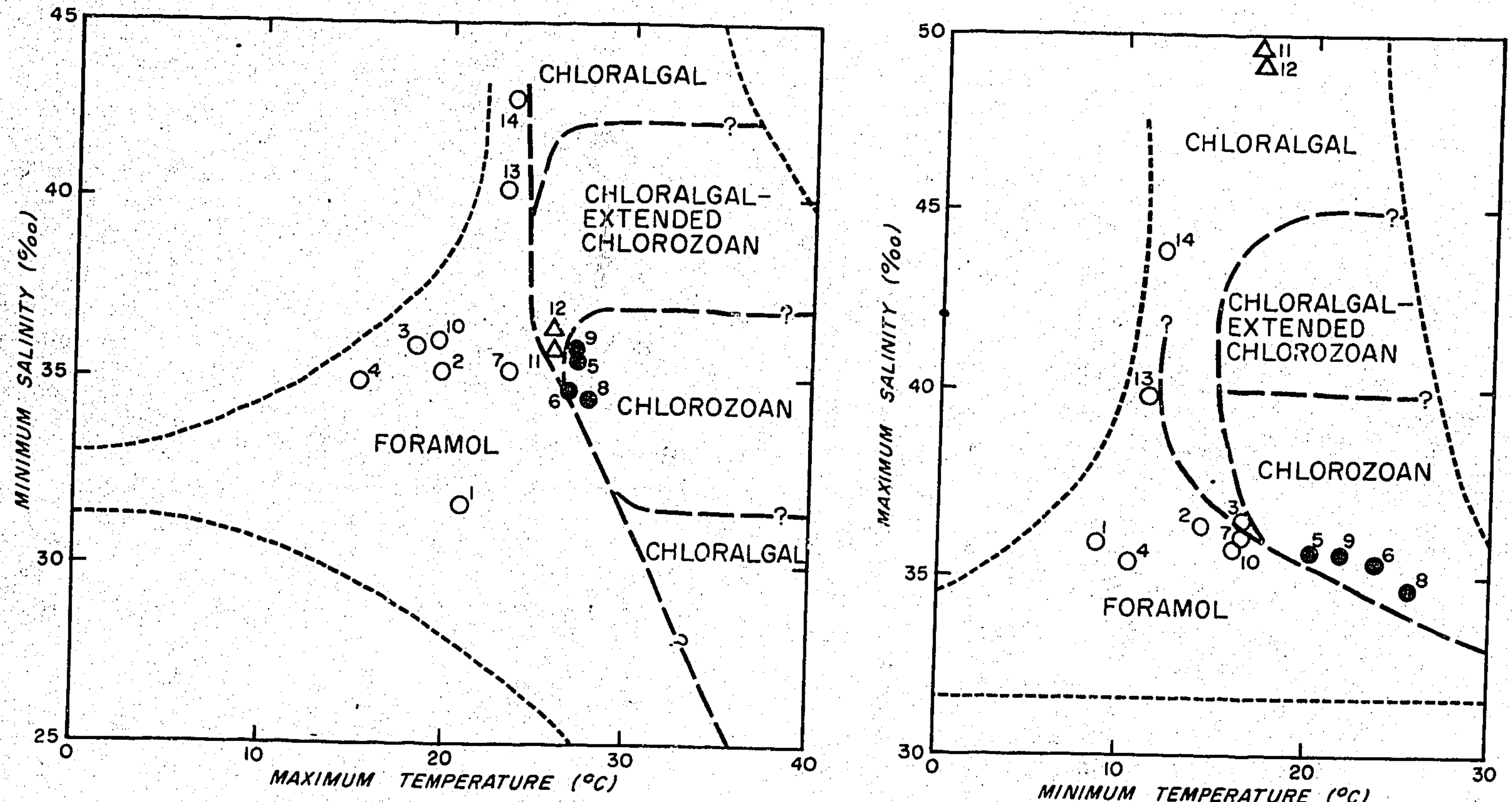


Fig. B4 Location of and section along transect 03, near Wood Point, showing depth of surface of buried sea-grass facies has been measured in cores and pits. The surface of the sea-grass facies consistently and gradually increases in elevation away from the sea, thus indicating a relative fall of low tide level of between 1 and 2 m during the construction of the regressive complexes. ^{14}C dates are being determined from samples of beach ridge carbonate to attempt to provide a calibration for this gradual sea-level fall.

The cementation textures of samples from the carbonate-lithified areas at Fisherman Bay have been studied. They revealed an association of textures, such as dripstone structures, internal pisoliths, lacy-carbonate fissure fillings, and internal sediment, that has not previously been described from an area of active megapolygon and teepee formation. However, ancient examples of this association are well described from the 'back-reef' facies of the famous Capitan Reef Complex (Permian, USA) and from the Triassic Calcare Rosso of Lombardy, Italy. The Fisherman Bay occurrence is likely to provide the key to the precise facies interpretation of such ancient occurrences. They are dominated by the precipitation of radial aragonite crystals (an unusual non-marine carbonate cement) in a regime of flowing groundwater discharge as a spring. The megapolygons with extensional plate boundaries are essentially the result of water escape.

The main skeletal components of the Spencer Gulf carbonates are gastropods, bivalves, foraminifera, and coralline algae. This assemblage is what would be expected for the area on the basis of salinity and annual temperature ranges (Fig. B5). The assemblage appears to be controlled more by water temperature than by salinity, for slightly higher water temperature conditions would shift Spencer Gulf into the chloralgal field. As it stands, Spencer Gulf sediments fit into the foramol grain association, but have lower proportions of bryozoans and barnacles than is usual for this association. This is probably due to the general lack of rocky substrates in the areas sampled but, at least as far as the Bryozoa are concerned, it may also be due to the relatively high salinities of northern Spencer Gulf limiting the colonisation by the generally stenohaline bryozoans.



Observed assemblage: O Foramol ● Chlorozoan △ Chloralgal

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1 *Port Phillip Bay, Victoria*
2 *SW Southern Australian Shelf*
3 *Great Australian Bight (Eastern part)*
4 *Tasmanian Shelf*
5 *Capricorn Complex, Great Barrier Reef*
6 *Southern part, Great Barrier Reef*
7 *Southern part, Eastern Australian Shelf (~34°S)*
8 *Sahul Shelf, eastern end (~10°S)*
9 *Rowley Shelf, western end (~22°S)*
10 *Rottnest Shelf, southern end (~34°S)*
11 *Shark Bay, sub-littoral Oceanic/Metahaline*
12 *Shark Bay, carbonate bank*
13 *Northern Spencer Gulf, Fisherman Bay area*
14 *Northern Spencer Gulf, Redcliff area*

Fig. B5 Salinity and temperature annual range (STAR) diagrams (after Lees, 1975), showing the plotted positions of Australian Shelf skeletal carbonate provinces. Data points 1-12 from Lees (1975)* and 13 and 14 from Shepherd (1973)**

* *Marine Geology, 19, 159-198.*

** *A preliminary report on the marine environment and fisheries of upper Spencer Gulf with recommendations for further studies. Report of the South Australian Department of Fisheries.*

SALINE LAKE STUDIES

SALINE LAKES OF EYRE PENINSULA

by

R.V. Burne, James Ferguson & J. Bauld

STAFF: J. Bauld, R.V. Burne, James Ferguson, L.A. Plumb, and P. De Deckker (Adelaide University).

These studies examine processes relevant to the formation and preservation of organic matter within restricted saline lake ecosystems which are often dominated by blue-green algae; the diagenesis of this material within a relatively undisturbed environment; and the groundwater chemistry and hydrology of lakes and their significance for the potential accumulation of carbonates, evaporites, and metals. These studies will provide data for models of Proterozoic and Cambrian hydrocarbon accumulation, and for models of formation of some ancient ore host rocks for which Recent saline lakes provide a reasonable analogy. During the year most attention focussed on the saline lakes of the Eyre Peninsula. These consist of a variety of geomorphological types, including (1) large coastal lakes, bounded by dunes and fed by both sea water seepage and groundwater springs, such as Lake Newland; (2) large pans, such as Lake Greenly, some with marginal lunette pond chains, such as around Lake Malata; (3) karst hollows, such as Pillie Lake; and (4) large internal drainage basins, or playas, such as Lake Gillies.

The lake waters show considerable chemical variation (Table B1); some are derived from sea water, some from continental groundwaters, and others from mixtures of the two. It is worth noting that although Sleaford Mere is an enclosed marine embayment, its waters are much less saline than sea water, indicating a substantial input of continental water into the lagoon.

The lake sediments consist mainly of combinations of quartz, calcite, aragonite, halite, gypsum, shell fragments, and charophyte oogonia, and, in contrast to the lake systems in the vicinity of the Coorong, there is no evidence of comtemporary protodolomite formation in the Eyre Peninsula lakes examined to date.

Coherent blue-green algal mats cover the marginal sediments of many lakes. Diatoms and photosynthetic bacteria also contribute to mat formation. Lake Damascus contains widespread thick mats of blue-green algae and photosynthetic bacteria. Samples of mat were collected from the Eyre Peninsula salt lakes for microscopy and identification of microbial components.

Table B1

Chemistry of saline lakes

		TDS/TDS SW	Na/Cl	Mg/Br	K/Br	Probable Origin
1.	Duck Lake	0.13	0.602	12.3	1.8	Non-marine
2.	Lake Wangary	0.15	0.582	13.7	2.1	" "
3.	Sleaford Mere 1	0.38	0.578			(?)
4.	Lake Newland: South	0.94	0.576	19.3	5.5	Marine
	North	1.02	0.567	20.0	5.9	"
5.	Lake Pillie	1.01	0.646	25.2	5.6	(?) Non marine
6.	Yangie Bay 1	1.04	0.565	18.3	5.2	Marine
7.	C.B.P. Lake Damascus	1.19	0.582	21.8	6.2	Marine
8.	Lake Tungketta	1.22	0.580	16.1	5.8	Marine
9.	Peake Bay, 3rd Lake	1.38	0.557	17.8	3.5	Non-marine
10.	Lake Malata:main	1.49	0.587	16.3	3.1	Non-marine
	: 1st Lunette	1.80	0.595	16.7	3.1	" "
11.	L.H.2. Lake Hamilton (Spring?)	3.05	0.543	19.8	5.45	Marine
12.	Lake Inneston, Top layer	3.22	0.543	21.1	5.05	Marine
	Bottom	3.44	0.514	19.9	4.9	"
13.	Lake Greenly	4.61	0.635	18.7	4.5	Non-marine
14.	Peak Bay, Lake 2	8.34	0.583	20.4	3.1	Non-marine
15.	Seawater	1	0.556	19.5	5.9	

OCCURRENCE OF BENTHIC MICROBIAL MATS IN SALINE LAKES

by

J. Bauld

STAFF: J. Bauld

The lack of a single coherent body of information concerning the occurrence, composition, and functional biology of microbial mats in salt lakes stimulated a comprehensive review of the widely scattered literature on this topic. While microbial mats may be constructed by one or more of a variety of microscopic eukaryotic algae (e.g., diatoms), blue-green algae, and photosynthetic bacteria, most salt lake mats are composed primarily of either filamentous or unicellular blue-green algae. In shallow lakes the mats may make a major contribution to the total primary productivity of the lake ecosystem. Not only do they provide convenient experimental systems for biologically oriented research but they are also of considerable importance to sedimentological, geochemical, and micropalaeontological investigations.

ANTARCTIC SALINE LAKES AND BLUE-GREEN ALGAL MATS: MODERN ANALOG OF PRECAMBRIAN GLACIAL SEDIMENTS

by

J. Bauld

STAFF: J. Bauld, M.R. Walter

Carbonate sediments are generally considered diagnostic of warm-water environments. The occurrence of dolomite and limestone beds within many Upper Proterozoic glacial deposits (tillites) has thus been a source of puzzlement and controversy. Stromatolites are also conventionally thought to be warm-water indicators. We have described two examples of stromatolitic dolomite which occur, together with barite, at the top of Upper Proterozoic tillites of the Amadeus and Ngalia Basins of central Australia. Problems of interpretation may be largely resolved after examination of the published data on Antarctic lakes. Carbonate sediments, sulphate evaporites, and even stromatolites are common components of cold arid-climate lakes. Antarctic lakes of high salinities occupy enclosed glacial basins in both the Vestfold Hills and the Taylor and Wright Dry Valleys. Lake Bonney, the most comprehensively described example of a modern hypersaline lacustrine system in a cold arid climate, contains a large-scale blue-green algal-mat/evaporative association. These stromatolitic mats and their constructing microbes are comparable to those described from warmer climates, e.g., Shark Bay and Bermuda. We suggest that environments such as this provide a modern analog of known Precambrian glacial sediments associated with carbonates, evaporites, and stromatolites.

IRON MINERALISATION OF INTERTIDAL CARBONATE SEDIMENTS BY SALINE CONTINENTAL GROUNDWATERS

by

James Ferguson

STAFF: R.V. Burne, James Ferguson, D. Fitzsimmons, L.A. Plumb.

One of the more contentious mechanisms invoked for the genesis of some types of sedimentary ore deposit involves low-temperature, near-surface continental groundwaters mobilising and transporting the ore-forming metals to marine sites of deposition. At Fisherman Bay, on the northeastern coast of Spencer Gulf (Fig. B1) there is a modern environment which combines the two major features of the ore-forming models - metal-rich, seawards-flowing continental groundwaters and a nearshore, marine-influenced area of metal accumulation. In this case the metals are Fe and Mn; the site of deposition is the interface of continental red-bed sediments and overlying intertidal and supratidal marine carbonates; and the product is a lens (Fig. B6) of iron mineralised sediments containing typically 30 to 70% Fe_2O_3.

The iron-mineralised sediments are centred on groundwater springs which discharge Fe and Mn-rich waters from highly permeable quartz sands within the heterogeneous clay and sand continental aquifer systems. The abnormally high Fe content (60 ppm) of these waters results from a combination of three factors: (1) Fe is available in a readily reactive form as ferric oxide coatings around sediment grains; (2) reducing conditions have become established in the lower parts of the aquifer system, without limiting the solubility of Fe by the generation of OH^- or S^{2-} ions; and (3) the aquifer sediments are free of carbonate and feldspar minerals which could buffer the groundwaters at near neutral pH. Consequently, oxidation and hydrolysis of Fe^{2+} in the more oxidised upper parts of the aquifer reduce the pH of the waters to unusually low values.

Where the acid, midly oxidised groundwaters are discharged in the intertidal zone they dissolve the carbonate component of the sediments, and the

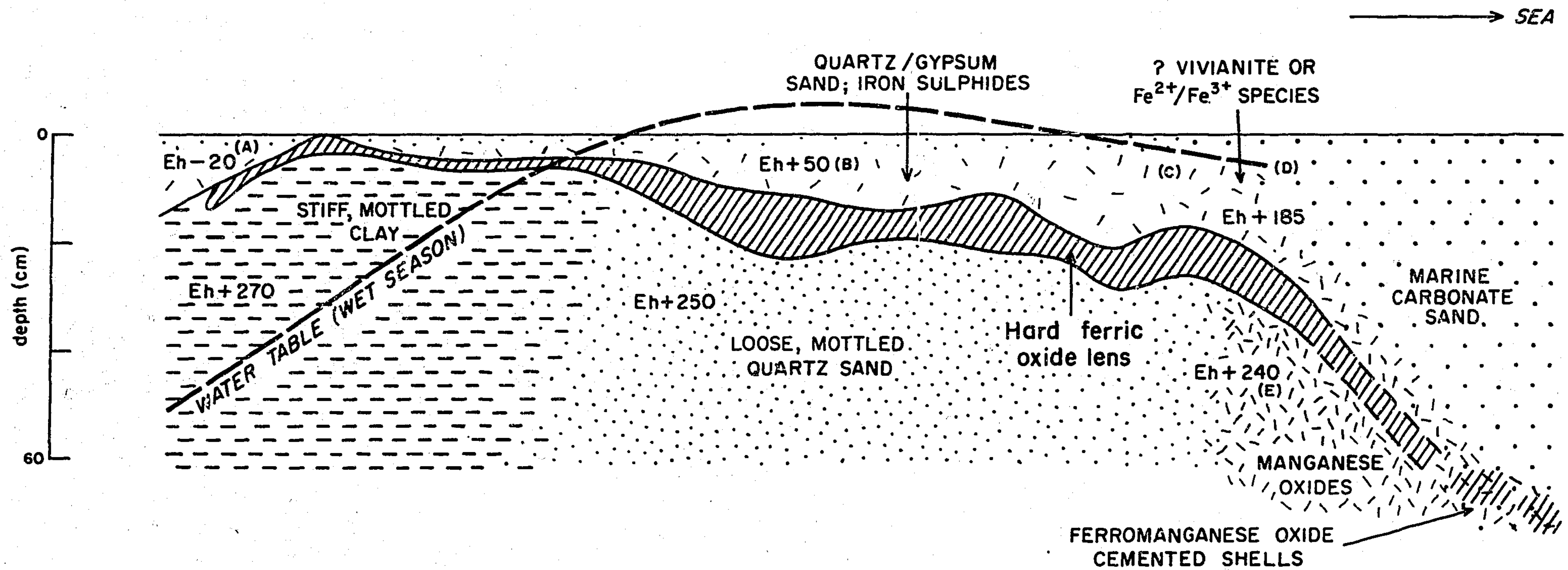

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Fig. B6 Environment of iron mineralisation at Fisherman Bay resultant increase in pH causes the precipitation of goethite and, at the fringe of the area where there is excess carbonate, manganese minerals. Comparison of the lithology and geochemistry of the Fe-rich Fisherman Bay sediments with those of modern and ancient iron ore deposits suggests that the closest analogy is to some types of ironstone. Ironstones can occur as restricted lenses; they range in thickness from a few centimetres to tens of metres and mostly they occur in the near-shore faces of shallow-water marine sequences. Both the Fisherman Bay Fe-lens and 'oxide' ironstones consist of a major fraction of limonite, some of which is in the form of ooids developed round cores of clastic material. Geochemically, the Fisherman Bay Fe lens is more akin to hematitie-quartz ironstones with volcanic associations, in that it is low in FeO and P. The P concentrations may be genetically significant as the low solubility of iron phosphates suggest that P could not be transported in Fe-rich groundwaters. High-P concentrations in some ironstones may be generated at the site of deposition.

The Fisherman Bay groundwaters and Fe-rich sediments contain only trace quantities of Cu, Pb, or Zn, although the theoretical solubility of these metals in the groundwaters is quite high. This lack of metals reflects the low metal contents of the predominantly quartz-feldspar continental red beds. Nonetheless, the basic hydrological and geochemical features of the Fisherman Bay system are similar to those proposed for the genesis of certain stratabound evaporite-associated Cu, Pb, and Zn ores, and the actions of this system on metal-containing, relatively unweathered aquifer sediments should generate significant base-metal concentrations.

BLUE-GREEN ALGAL MATS: ACTIVITIES OF GEOBIOLOGICAL SIGNIFICANCE

PRIMARY PRODUCTIVITY IN BLUE-GREEN ALGAL MATS, SPENCER GULF, SA

by

J. Bauld

STAFF: J. Bauld

The intertidal mats of northeastern Spencer Gulf generally consist of thin surface layers, 1-2 mm thick, of living filamentous blue-green algae which cover the accumulations of black FeS resulting from bacterial sulphate reduction. The energy requirements for sulphide production by sulphate-reducing bacteria are apparently supplied by the photosynthetic activities (lightdependant CO_2 fixation) of the blue-green algae.

In the field, primary productivity (photosynthetic CO_2 fixation) is determined experimentally by a radio-isotopic method employing ^{14}C-labelled carbonate. Small samples of blue-green algal mats are incubated with the radio-isotope for short periods. Since the 1979 Annual Summary of Activities (BMR Report 222) appeared, further investigations have been carried out. In particular, experiments were done during the winter months to confirm data, previously obtained during summer, about the effects of variations in salinity and daily light intensity on photosynthesis.

In agreement with previous experiments (see Annual Summary of Activities, 1979) the photosynthetic activity of smooth mat exhibited a wide salinity tolerance having a broad optimum around 70°/oo (twice sea-water salinity). However, attempts to measure photosynthetic variation during the sunrise-sunset period were inconclusive because of inclement weather.

The effect of incident light intensity on photosynthetic CO_2 fixation by smooth and tufted mats was examined. Smooth-mat photosynthesis appeared to be light-saturated above light intensities of 300-400 $\mu m\ m^{-2}\ s^{-1}$ (ca 50% of incident light intensity) whereas tufted mat photosynthesis continued to increase with increasing light intensity up to ca 700 $\mu E\ m^{-2}\ s^{-1}$ (ca maximum incident light intensity during the experiment, done in July).

These data are consistent with the growth habits of the two mats examined. Smooth mat may have a thin transient cover of sand grains which is deposited and removed by wave action. Rapid physiological adaption to the reduced light intensity is a likely consequence. Tufted mat, on the other hand, has a more variable topography and much of the mat consists of peaks and ridges on which sand grains do not settle. It is thus exposed to higher light intensities than neighbouring smooth mat, and is physiologically adapted to this regime.

PRODUCTION AND FATE OF ORGANIC CARBON IN BLUE-GREEN ALGAL MATS

by

J. Bauld, L.A. Plumb

STAFF: J. Bauld, L.A. Plumb, H.M. Thomas, G. Trengove

The contiguous and clearly delineated association between blue-green algal primary productivity and bacterial sulphate reduction, together with the lack of other major organic inputs, strongly suggests that the phototropic activities of the living algal mat provide the organic carbon required for heterotrophic bacterial processes including sulphate reduction.

In this context the partitioning of photosynthetically fixed CO_2. carbon between blue-green algal biomass (Particulate Organic Carbon = POC) and soluble, excreted material (Dissolved Organic Carbon = DOC) assumes considerable significance since the DOC provides a source of immediately available organic carbon for heterotrophic uptake by, for example, sulphate-reducing bacteria. In contrast, utilisation of POC is delayed because it requires decomposition and solubilisation before it can be metabolised by sulphate reducers (see Fig. B7). This project, which is now supported by an AMSTAC grant, is proceeding along several interdependent lines which are described below.

Quantitative and qualitative studies of DOC have commenced. Preliminary field experiments indicated that some 5-15% of the carbon fixed photosynthetically is rapidly excreted. At the time, these values were considered slightly high but not unreasonable. Later, values as high as 25-30% prompted an examination of experimental technique. Subsequent fieldwork has shown that the use of formaldehyde to ^{14}C-incubations results in an overestimate of DOC excretion, compared with a newly devised filtration technique. On the basis of limited data available thus far, DOC excreted by blue-green algae in the mats is more likely to be about 5% of total fixed CO_2 carbon rather than the higher values obtained earlier. Follow-up laboratory studies, using cultures of blue-green algae isolated from the mats, are currently in progress.

In addition to quantifying the DOC excreted by photosynthetically active components of the blue-green algal mats we have started to identify and measure those components of DOC which are potentially utilisable by sulphate-reducing bacteria. A considerable period of time has been spent developing satisfactory extraction and analytical techniques for the determination of low molecular weight organic compounds in both blue-green algal mat sediments and laboratory cultures. Successive ion-exchange treatments give satisfactory desalting and reasonable separation of representative aliphatic acids, amino acids, carboxylic acids, and carbohydrates from solutions of salinity about three times that of normal sea water. Further work is required to optimise these and other separation and analytical techniques.

DOC produced by cultures of mat-forming blue-green algae has been concentrated by freeze-drying and then fractionated by ion-exchange chromatography. Most of the organic compounds are of low molecular weight. About 10% appeared to be amino acids.

Field studies of residual DOC distribution in mat sediments and its

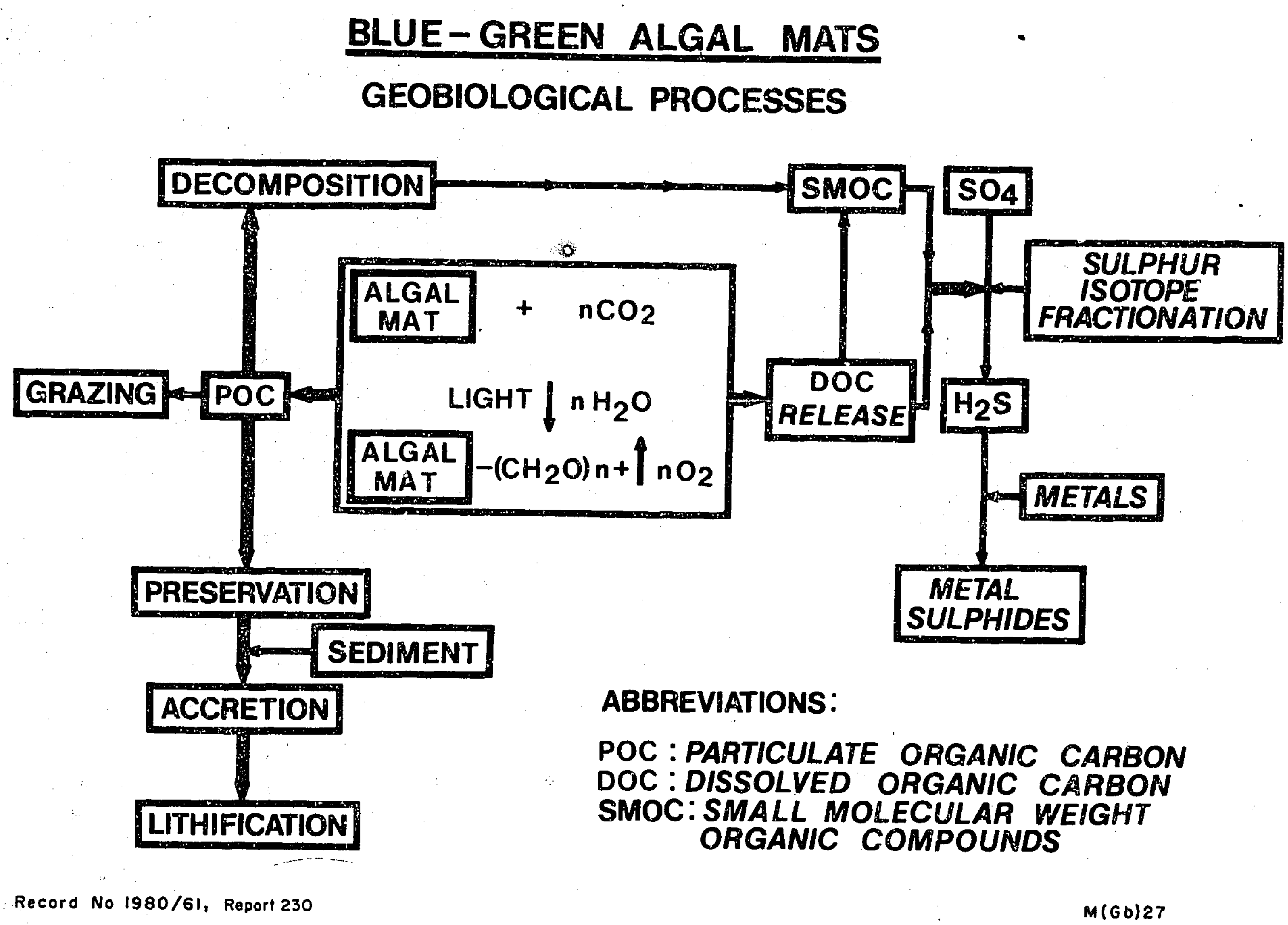

Fig. B7 Flow diagram of processes occurring in blue-green algal mats showing the inter-dependence between biological, sedimentological, geochemical, and hydrological phenomena spatial relationship to sulphate reduction have commenced. Results from one such experiment are shown in Table B2. DOC appears to move rapidly from the photosynthetically active surface layer to the underlying layers. These data are consistent with experiments which show that the zone of maximum sulphate reduction is very closely associated with photosynthetically active blue-green algal mat.

Table B2

^{14}C-DOC in cyanobacterial mat and sediment sections after incubation with ^{14}C-carbonate.

Doc is expressed as a proportion of the total to 2.0 cm depth after 1.5 h incubation.

Incubation Time h	Sections Mat	0-0.5 cm	0.5-1.0 cm	1.0-1.5 cm	1.5-2.0 cm	Total
0.5	.06	.1	.05	.02	.01	.24
1.0	.14	.19	.1	.05	.02	.50
1.5	.24	.33	.26	.12	.05	1.00

Substantial effort has resulted in the successful enrichment of two mat-constructing blue-green algae. Cultures of each organism now contain only one blue-green alga (i.e., are unialgal) but remain contaminated with heterotrophic bacteria. Modifications to the culture medium have substantially enhanced the yield of these unialgal cultures. Work continues on the purification of cultures and the determination of their optimal growth conditions.

SULPHATE REDUCTION IN ALGAL-MAT SEDIMENTS

by

G.W. Skyring

STAFF: J. Bauld, I.A. Johns, L.A. Plumb, M.R. Reed, G.W. Skyring

Sulphate reduction rates in mat-covered sediments in Spencer Gulf SA from November 1977 to November 1978 varied from <0 to 160 mmol $m^{-2} d^{-1}$ and the average, median, and mode of 220 estimates was 21, 15 and 2 mmol $m^{-2} d^{-1}$, respectively. Highest sulphate reduction rates occurred during autumn and spring and an annual estimate for sulphate reduction was 6.5 mol m^{-2}, but in some regions of the mat it may be as high as 12 mol m^{-2}. The highest sulphate reduction rates occurred in the uppermost 0.1 cm of the sediment, close to metabolically active mat. The molar ratio for primary productivity (CO_2 fixed photosynthetically) and sulphate reduction rates was estimated at 2:1 on an annual basis. Photosynthetically fixed carbon appeared to interact with the sulphate reduction process 4 to 8 weeks after its formation.

There were no detectable differences between sulphate reduction rates measured during day or night. Sulphate reduction appeared to be stimulated only by glucose and a complex mixture of growth nutrients. The sulphate reduction rates estimated for 28-day periods could generally account for the sulphide to be regenerated in the 0 to 1 cm layer of the sediment on a monthly cycle. The sulphide in layers below 2 cm may be preserved for several months rather than days.

CARBON, SULPHUR RELATIONSHIPS

In addition to constraints imposed by the environmental chemical and physical factors on sulphate reduction, the rate at which organic nutrients are supplied to the sulphate-reducing bacteria has a limiting effect. It was apparent that, in the intertidal zone, precipitated iron sulphides were almost exclusively associated with areas that were covered by algal mat. It appeared therefore that, in this environment, the blue-green algae in the mat were providing the organic nutrients to drive sulphate reduction, and indeed the results of several experiments demonstrated that sulphate reduction rates were highest in the uppermost 5 mm of sediment underneath green, healthy mat. However, both simple and multiple regression analyses, in which sulphate reduction rate was the dependent variable, showed that there was no detectable correlation between sulphate reduction rates in mat-associated sediments and primary productivity data. The most obvious reason for this was that the rate of biodegradation of the photosynthetically synthesised, high molecular weight organics (POC) was likely to be rate limiting for the sulphate-reducing microorganisms.

In laboratory studies, Bubela, Ferguson, & Davies (1975) showed in a simulated sedimentary system that the rate of sulphide production in buried, decaying mat from Spencer Gulf was maximal over the first 30 days. In addition, Bauld (this Annual Summary) showed that the algae in the mat produced 5-15% dissolved organic carbon (DOC) during active photosynthesis. On the basis of these observations, time series models, which described the rate of mat degradation to small organic molecules, were used to transform the original primary productivity values determined by Bauld. The time series models released 10% (as DOC), 50%, and 25% (as SMOC) of the photosynthetically fixed carbon, at the time of fixation and one and two months later respectively. In another model, 0, 25, 25, and 25% of the primary productivity was made available for sulphate reduction over a period of three months. Regression analyses showed that for both models there was now a significant positive linear correlation between the transformed primary productivity rates and sulphate reduction rates. While there were data missing for the inundation periods not monitored it is considered that the correlations are not purely fortuitous. The analyses support the idea that a slow degradation of macromolecular organic carbon occurs over a period of 2 to 3 months and that low molecular weight organic molecules resulting from this diagenetic process are utilised in sulphate reduction. The slope of the regression for all data was 1.24 ± 0.33 and the intercept was close to the origin (+0.7), suggesting that most of the primary productivity carbon was eventually involved in sulphate reduction. However, the slope in this analysis relates the daily rates of primary productivity and sulphate and does not account for the facts that (1) photosynthesis begins immediately the mat is wet by tidal (or rain) waters and continues at maximal rates until the inundation finishes, and (2) sulphate reduction peaks during an inundation period (see 1979 Summary of Activities - BMR Record 1979/61 or BMR Report 222).

To derive a more realistic relationship between primary productivity and sulphate reduction, the calculated annual sulphate reduction rate of 6.5 mol m^{-2} was compared to an estimate for annual primary productivity of 13.5 mol m^{-2} and the resulting ratio of carbon fixed to sulphate reduced was 2:1. This ratio was calculated from the data for all three stations combined, but it was also close to the separate values of 1.7, 2.4, and 2.1 calculated for the experimental stations 4M, 8M, and 10M separately. These calculations are subject to error of about $\pm$ 40%, so the ratio of the rates of primary productivity to sulphate reduction could be from 1 to 4.

GENERAL USEFULNESS OF THE EQUATIONS RELATING SULPHATE REDUCTION RATES AND ENVIRONMENTAL FACTORS

Although the mat-covered sediments in Spencer Gulf are representative of fairly rare marine environments in the mo world, they undergo such a variety of physical regimens that the equat relating sulphate reduction rates with these physical factors may have general predictive usefulness. The data relating temperature of incubation and sulphate reduction rate (Arrhenius plot, Annual Summary 1979) were not included in the data used in the multiple regression analyses and, therefore, they may be used as an independent indicator of the usefulness of the question: SSR* = 0.89C + 0.88T 1.76 PW - 0.10 SAL - 46 (1). The measured rates of 4, 10.5, 25, and 31 at 10, 20, 30, and 40°C respectively agreed well with the predicted rates of 5, 14, 23, and 31. The values for C, PW, and SAL were 18, 22, and 121 respectively for this experiment. Equation 1 is not applicable at elevated temperatures with respect to the variable C which is too low to account for the sulphate reduced. Suppose a situation in which, at maximal sulphate reduction rates in a tightly coupled system, the ratio between primary productivity and sulphate reduction was 2:1 (see above) then to give the measured (and predicted) values for sulphate reduction rates in the temperature variation experiment, a value of primary productivity of 62 and a coefficient of 0.26 for C in the multiple regression analysis would be required. The model, therefore, may be validly extended to various C/S ratios (and actual values) provided that there are some experimental data to provide a check point.

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* SRR = sulfate reduction rate, mmol m^{-2} d^{-1}.

C = organic carbon synthesized by the primary producers mmol m^{-2} d^{-1}.

T = °C.

PW = % water by weight.

SAL = salinity as °/oo NaCl.

The multiple regression model was also tested against sulphate reduction rates calculated for marine environments in other parts of the world. The sediments from other environments were presumed to contain maximal water and thus the value of 25% (the average of all values used in the present studies) was used. In the present studies the pore-water content was probably an indirect measure of anaerobiosis and 25% moisture was among the higher values measured. In these comparisons the following regression was used:

$$SRR = 0.26C + 0.88T + 1.76\ PW - 0.1\ SAL - 46$$

Jorgensen (1977) calculated the average sulphate reduction rate (9.5 mmol $m^{-2}\ d^{-1}$) for Limfjorden sediments from March 1974 to December 1975; the salinity varied from 23 to 29°/oo. We calculated an average temperature of 12° from his data. Using the above equation and these data, an average sulphate reduction rate was calculated at 15 mmol $m^{-2}\ d^{-1}$, which is not too far from the experimental result obtained by Jorgensen. Jorgensen & Cohen (1977) give data for the sulphate reduction rate in surface sediments of Solar Lake and from the above regression it was calculated that a C value of 195 would be required to permit the measured sulphate reduction rate of 54 mmol $m^{-2}\ d^{-1}$ at 24°C and 156°/oo salinity. The C requirement of 195 mmol $m^{-2}\ d^{-1}$ is at the lower end of the range of 200 to 1000 mmol C $m^{-2}\ d^{-1}$, calculated for primary productivity of the algal mat in Solar Lake. A similar calculation for C in tall *Spartina* marsh soils supporting high rates of sulfate reduction (Skyring & others, 1979) gave a value of about 700 mmol C $m^{-2}\ d^{-1}$, which is approximately 20% of one estimate for primary productivity of tall *Spartina*.

Thus the equation derived by the multiple regression analysis does appear to have some general usefulness in describing the simultaneous effects of temperature, salinity, and organic carbon availability on sulphate reduction in marine environments.

SULPHIDE IN THE SEDIMENT: ITS QUANTITATIVE RELATIONSHIPS TO THE CALCULATED SULPHATE REDUCTION RATES AND FACTORS WHICH CONTROL ITS PRESERVATION

It is apparent that sulphide does not accumulate in these sediments. The average sulphide concentrations for sediments from stations 4M, 8M, and 10M at the end of the year were 15, 56, and 34% respectively of the calculated total sulphide production. Plumb (Annual Summary, 1979) determined the sulphur isotope abundances in the sulphides from samples of these intertidal sediments taken at the same time and location as those for the present experiments. For the sulphide from the 0-2 cm layer from all stations, there was significant negative correlations between the $\delta^{34}S$ values and ambient temperature. These results indicated that most of the sulphide in this layer of the sediment was produced in a short period before sampling (30 days) and that the sulphide produced before that was lost from the sediment. The sulphate reduction rates calculated for the month before sampling could account for the sulphide found in the 0-1 cm layer for 27 out of the 39 sampling periods at all stations. However, these sulphate reduction rates could not account for such a rapid replacement of sulphide in layers below 1 to 2 cm and it is possible that under the appropriate conditions sulphide is preserved for months rather than days in these lower layers. For example, there were significant correlations between the sulphide content of all samples from the 0-5 cm layer and primary productivity rates and sulphate reduction rates. One interpretation is that cyanobacterial mat with high primary productivity is relatively impermeable thus maintaining an anoxic environment conducive to sulphate reduction and retarding the rate of oxidation of the sulphide.

Sulphide was precipitated in these sediments mainly as FeS (acid soluble). Pyrite has not been detected chemically but framboids of iron sulphide were occasionally seen while examining sections in the scanning electron microscope. The average iron content of the sediment was 1% and at the highest concentrations, sulphide was combined with all of the available iron. On average, however, about 10% of the iron was combined with sulphide.

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ISOTOPE STUDIES IN THE MODERN ENVIRONMENT

by

L.A. Plumb

STAFF: R.V. Burne, James Ferguson, D. Fitzsimmons, L.A. Plumb, M. Thomas, P.A. Trudinger.

Examining the relation between the geochemistry, biology, and sedimentology of the paralic sedimentary sequences of the northeastern shore of Spencer Gulf, South Australia, is greatly assisted by the use of sulphur, deuterium, and oxygen isotope distributions. The implication that marine, continental, and mixed brines are involved in the geochemical processes at four localities in Spencer Gulf (see Ferguson & Plumb, 1978)* has been reinforced by additional deuterium and oxygen isotope data. Figure B8 presents all Spencer Gulf water data as a δD vs $\delta^{18}O$ plot, and representative values for both water and dissolved sulphate are shown geographically.

The isotopic composition of water varies, largely as a result of fractionation due to evaporation and condensation. Hydrogen isotopes are fractionated in proportion to the oxygen isotopes, and there is a worldwide correlation between D and ^{18}O contents of precipitation, where both delta values are relative to Standard Mean Ocean Water (SMOW) taken as zero. $\delta D = 8\delta^{18}O + 10$, where

$$\delta D = \left[\frac{D/H \text{ sample}}{D/H \text{ SMOW}} - 1 \right] \times 10^3 \text{ and } \delta^{18}O = \left[\frac{{}^{18}O/{}^{16}O \text{ sample}}{{}^{18}O/{}^{16}O \text{ SMOW}} - 1 \right] \times 10^3$$

The relationship is represented by the solid lines in Figures B8 and B9, and is known as the meteoric water line. This relates to latitude and is principally controlled by temperature. The isotopic composition of meteoric groundwaters alters in arid regions - fractionation accompanying evaporation results in concentrated meteoric waters exhibiting more positive delta values than for the original precipitation. In general, values become more positive farther seawards as a result of an increasing contribution from sea water (δD and $\delta^{18}O = 0$) and sea water sulphate ($\delta^{34}S \approx +21$ °/oo). This is

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* Baas Becking Geobiological Laboratory Annual Report for 1978; also in BMR Report 212

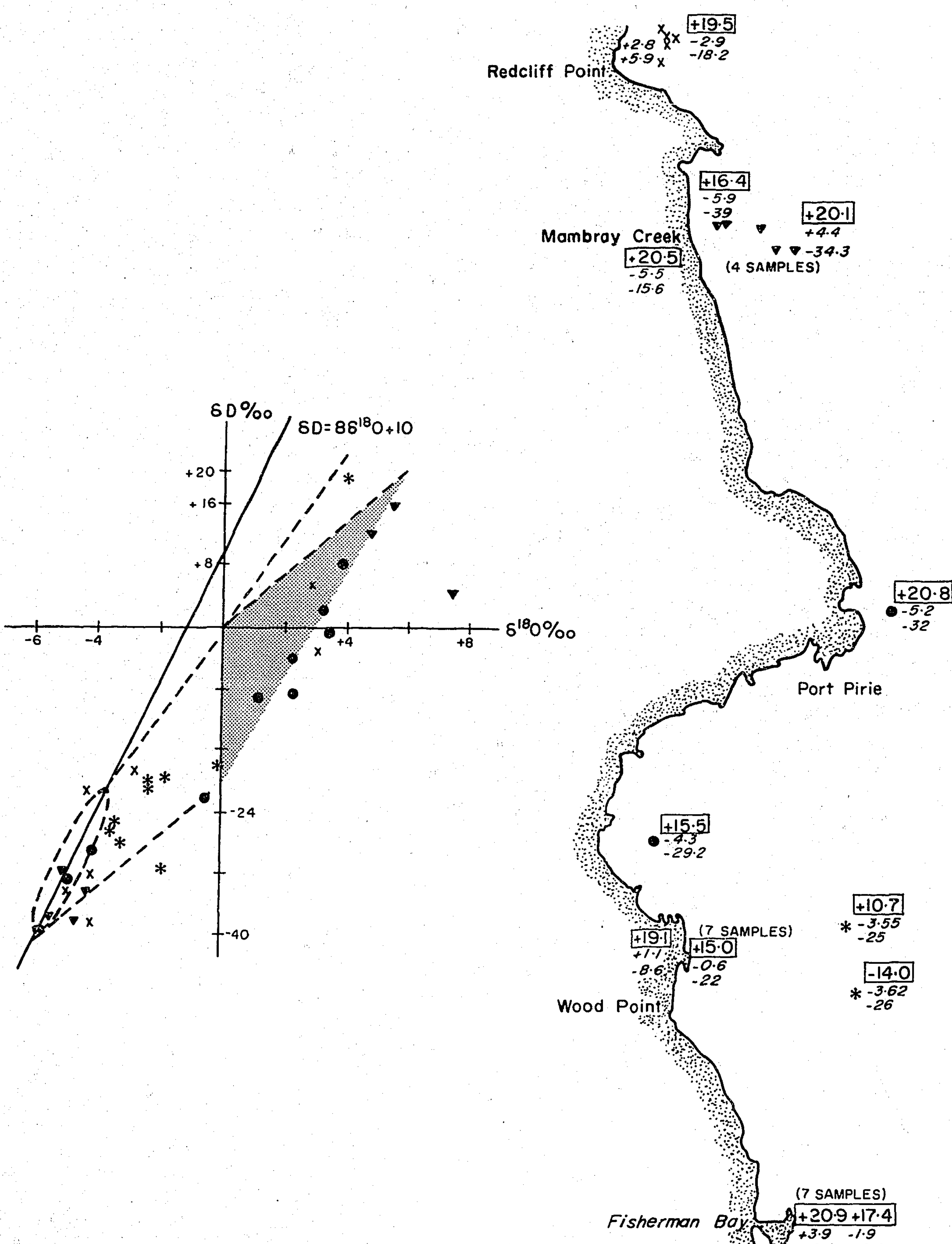

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Fig. B8 δD and δ18O values for groundwaters from sites (●,▼,*,x) along the northeastern shore of Spencer Gulf. Enclosed area along meteoric water line represents range for precipitation. Dashed lines show possible limits for waters derived by evaporation from a meteoric source (negative quadrant) or from seawater (positive quadrant). Values within the hatched area may arise by mixing. Sulphate isotope values for dissolved sulphate representative for the sites are also shown (boxed).

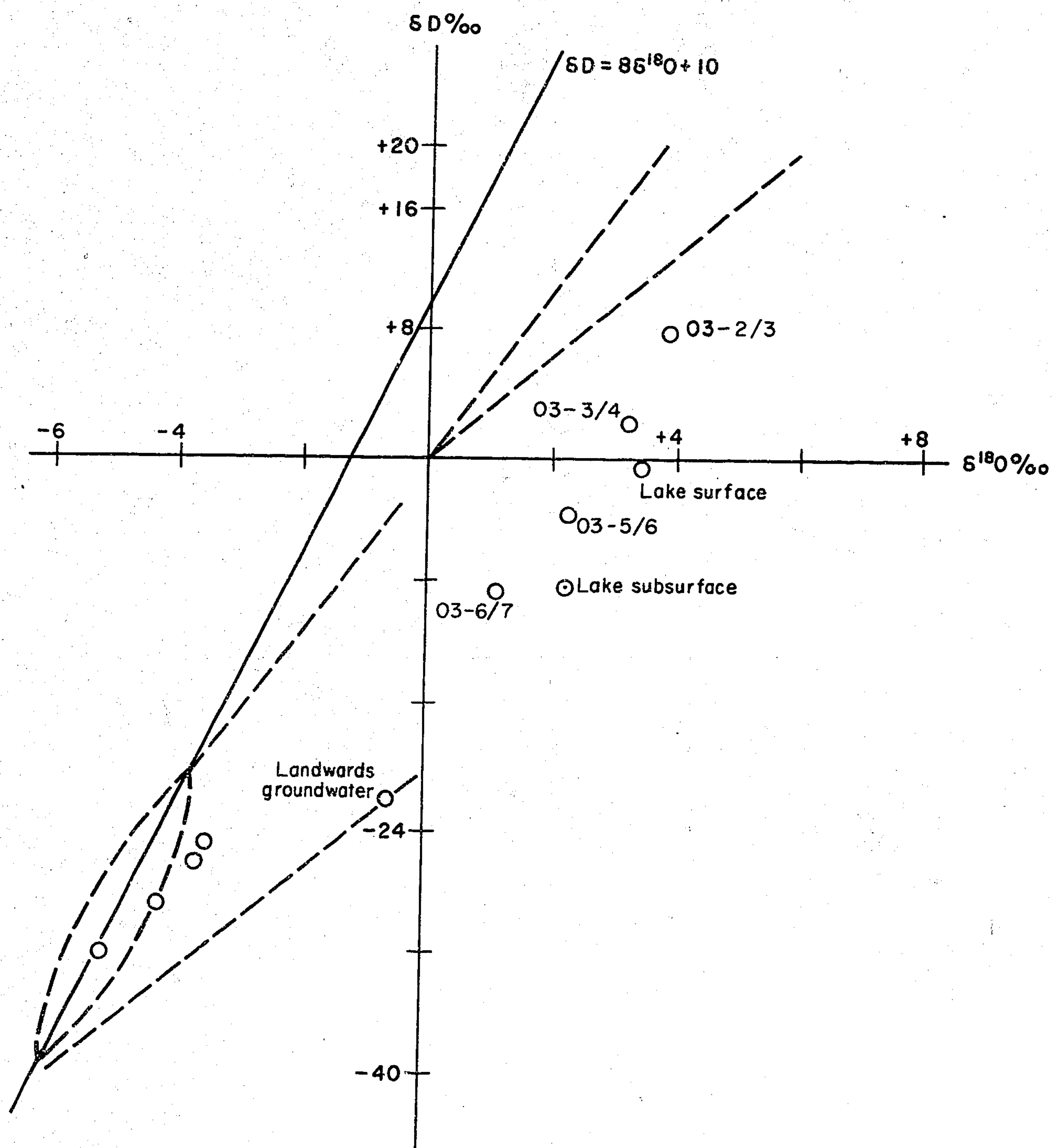

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Fig. B9 δD and $\delta^{18}O$ values for groundwaters (1) in transect across an ephemeral lake in the Wood Point area. Explanatory notes as for Fig. B8.

corroborated by chemical data for the Redcliff Point area (Table B3). Samples from the transect 01 show sea water characteristics except for the most landward (01-7) for which the Na/Cl ratio suggests solution of halite. This ratio is similar to those of waters from a nearly borehole (W170) and several resurgences (DHC1 and 2) for which the δD and $\delta^{18}o$ values suggest a meteoric origin. The $\delta^{34}S$ values are not inconsistent with dissolution of previously formed evaporites.

Table B3. Isotope distributions and ion ratios for groundwaters in the Redcliff Point area (Fig. B8).

For seawater Na/Cl = 0.86 and K/Br = 12.1 in milliequivalent ratios.

SAMPLE LOCATION	Na/Cl meq	K/Br meq	δD °/oo	$\delta^{18}S$ °/oo	$\delta^{34}S$ °/oo	
01-3	0.85	12.4				
01-5	0.86	13.0				SEAWATER
01-6	0.87	15.0				BRINES
PA1	0.84	14.7	+5.9	+2.8		
01-7	0.93	14.9			+18.6	DILUTE
DHC1	0.98	11.6	-31.7	-4.2	+20.7	CONTINENTAL
DHC2	1.03	10.2	-37.4	-4.4	+19.3	RESURGENCES
W170	0.95	11.8	-18.2	-2.9	+19.5	

Figure B10 presents the deuterium and oxygen isotope distributions for groundwaters associated with an ephemeral lake (Lake 19) near Wood Point. This lake has formed in a deflation zone which is isolated from the intertidal flats by stranded beach ridges, and which is intermittently flooded by seasonal elevation of the water-table. The progressively more positive δD and ^{18}O values from the supratidal plain to the intertidal zone support the preliminary assessment of continental groundwaters meeting and mixing with marine brines. This concept was formulated largely on the basis of the relationship between the sulphur isotope distribution in dissolved and precipitated (gypsum) sulphate. Figure B10 compares these distributions with the δD and $\delta^{18}O$ values and the Mg/K ratio. The zone immediately seawards of the lake appears to be the farthest inland marine influence. Evaporative effects appear to influence the groundwaters within the lake.

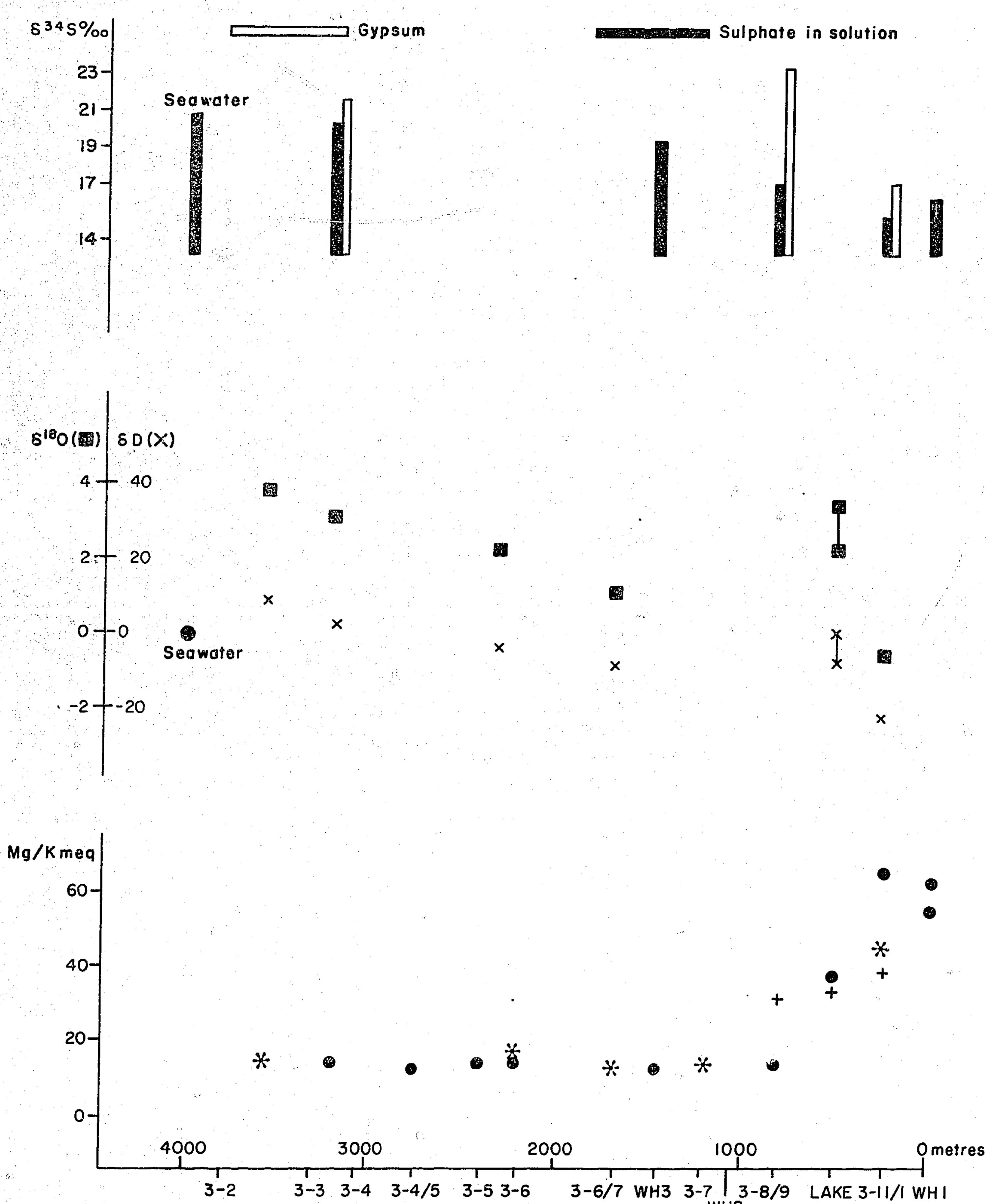

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Fig. B10 Comparison of changes in groundwater isotope composition, sulphur isotope distribution of dissolved sulphate and gypsum, and Mg/K meq ion-ratio from the intertidal zone to the supratidal plain. Different symbols for the Mg/K ratio indicate separate sampling times.

BIOCHEMICAL STUDIES ON A DEEP-SEA SEDIMENT - BALI TROUGH, INDIAN OCEAN

by

P.A. Trudinger

STAFF: P.J. Cook (Australian National University), L.A. Plumb, M. Thomas, P.A. Trudinger

Studies have been undertaken on a core from an anoxic sediment in the Indian Ocean to obtain information on the biogeochemical processes within the sediment, particularly with respect to the relation between sulphur and carbon transformations. The core was obtained from a water depth of about 3600 m at Site 39, located on the northwesterly extension of the Bali Trough, a fore-arc basin. The sediments are olive-grey nannofossil, foraminiferal, diatomaceous, radiolarian-bearing clays, and silty clays; montmorillonite is the dominant clay mineral, and illite and kaolinite are somewhat less abundant. The main sulphide mineral is pyrite, present in framboidal form, which exhibits an unusual (for modern sediments) isotopic pattern in that there is a close correlation (r=0.901) between increasing enrichment in ^{32}S and depth (see also 1979 Annual Summary of Activities).

Some of the changes in pore-water chemistry with depth for Core 39 are shown in Table B4. Sulphate is depleted and this is accompanied by increases in ammonia, and total alkalinity and by losses of Ca and Mg relative to Indian Ocean seawater. The changes in sulphate, NH_3, and alkalinity are closely correlated with r values of 0.920 and 0.66 for ΔSO_4-S versus alkalinity and ΔSO_4-S versus NH_3 respectively.

Table B4. Chemical trend in porewater of Core 39 as a function of depth

Depth (cm)	P	ΔSO_4^{2-}	NH_3 (a)	Alk^y (b)	$\Delta 2Ca$ (c)	$\Delta 2Mg$ (d)	ΣCO_2 (b)+(c)+(d)-(a)	ΣCO_2 / ΔSO_4^{2-}
0	0.08	14.7	1.46	14.9	10.8	7.1	31.3	2.13
109	0.085	23.9	1.83	21.0	14.9	12.2	46.3	1.94
215	0.074	23.2	2.14	20.6	14.1	12.5	45.1	1.94
369	0.032	20.5	2.74	19.3	13.6	4.6	34.8	1.70
522	0.034	21.4	2.89	21.8	13.2	-7.2	24.9	1.16
676	0.034	25.8	2.94	21.4	15.2	13.0	46.7	1.81
815	0.027	25.8	3.54	22.1	16.7	11.1	46.4	1.80

Estimates of total CO_2 production were made using the following formula:

$$\Sigma CO_2 = \text{alkalinity} - NH_3 + \quad \Delta 2CA^{2+} = \quad \Delta 2Mg^{2+}.$$

Comparison of these estimates with the observed depletions of sulphate in Core 39 shows that, with one exception, the ratio of $\Sigma CO_2 : \Delta SO_4^{2-}$ approximates 2:1 (Table B4). This accords with the theoretical relationship $2(CH_2O) + SO_4^{2-} \cdot H_2S + 2CO_2 + 2OH^-$, and indicates that sulphate reduction is the main process responsible for organic matter degradation and production of bicarbonate alkalinity in this sediment.

Based on the estimated total CO_2 produced and the changes in P and N (Table B4), the average C:N:P of organic matter decomposed in the upper 200 cm of sediment is 100:4.5:08. This ratio is close to that (100:4.5:0.1) reported for the first few metres of core 147 from DSDP Leg 15 in the Carribbean Sea. Below 200 cm, however, phosphate decreases and nitrogen increases relative to total CO_2 (Av. C:N:P - 100:8.4:0.03). Disappearance of phosphate may be due to calcium phosphate formation, and increases in ammonia may indicate a change in metabolism of organic matter to a more nitrogenous fraction.

ORE GENESIS INVESTIGATIONS

The general aim of the ore genesis studies is to determine the origin of various stratabound base-metal sulphide mineral deposits and to ascertain which characteristics of the deposits could, in the future, serve as exploration guides.

STUDIES IN THE ADELAIDE GEOSYNCLINE AND STUART SHELF
by I.B. Lambert

STAFF: T.H. Donnelly, J. Knutson, I.B. Lambert, P.M. Ryan

The main objective of these investigations is to compare the isotopic, geochemical, mineralogical, and petrographic features of mineralised and unmineralised strata from several regions in an attempt to define metallogenic processes and exploration guides. Areas of study are shown on the locality map Figure B11, and proposed stratigraphic correlations between the geosyncline and the shelf are summarised in Figure B12.

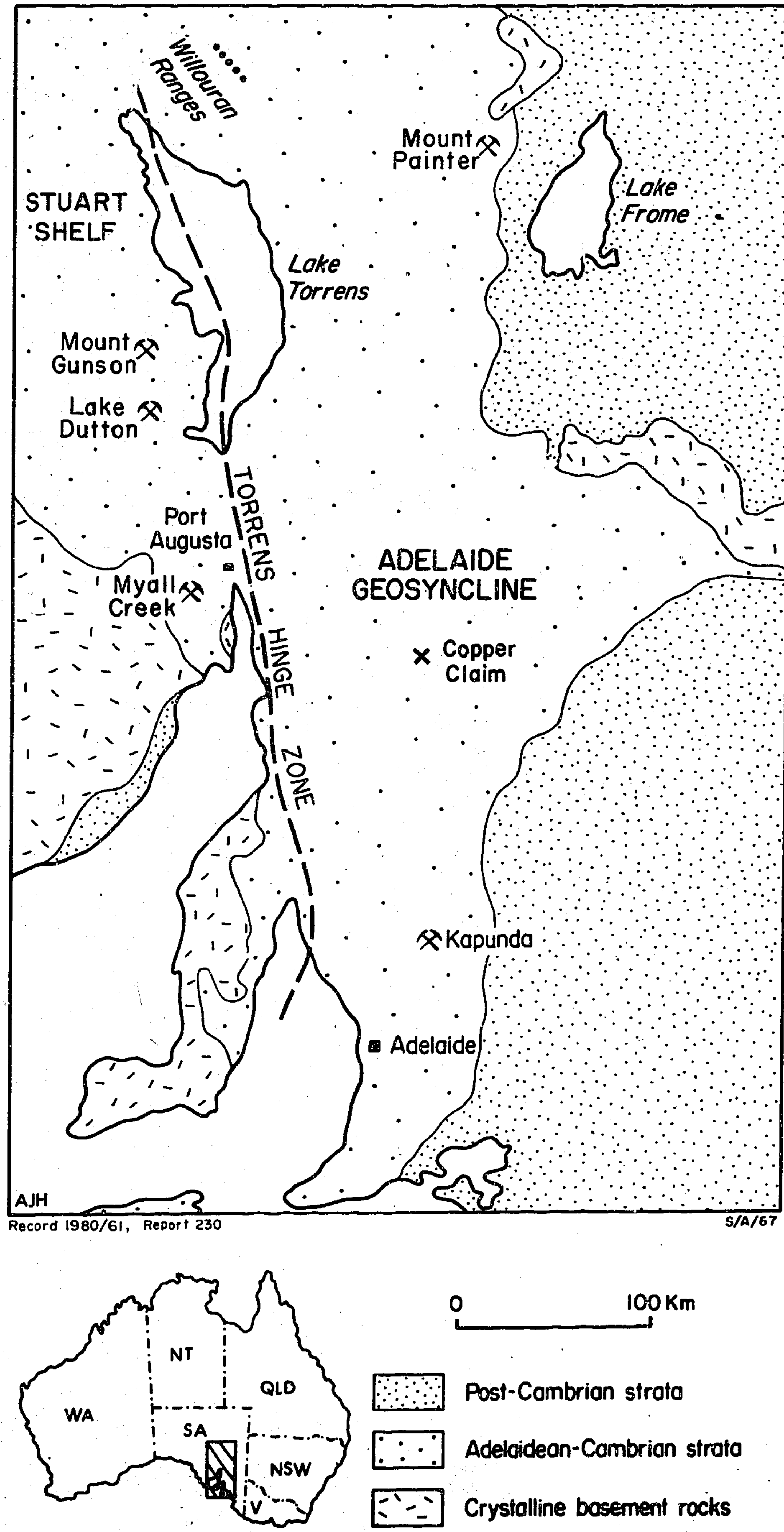

Fig. B 11 Sketch map showing locality of the copper-rich areas under investigation, and major geological features of southern South Australia

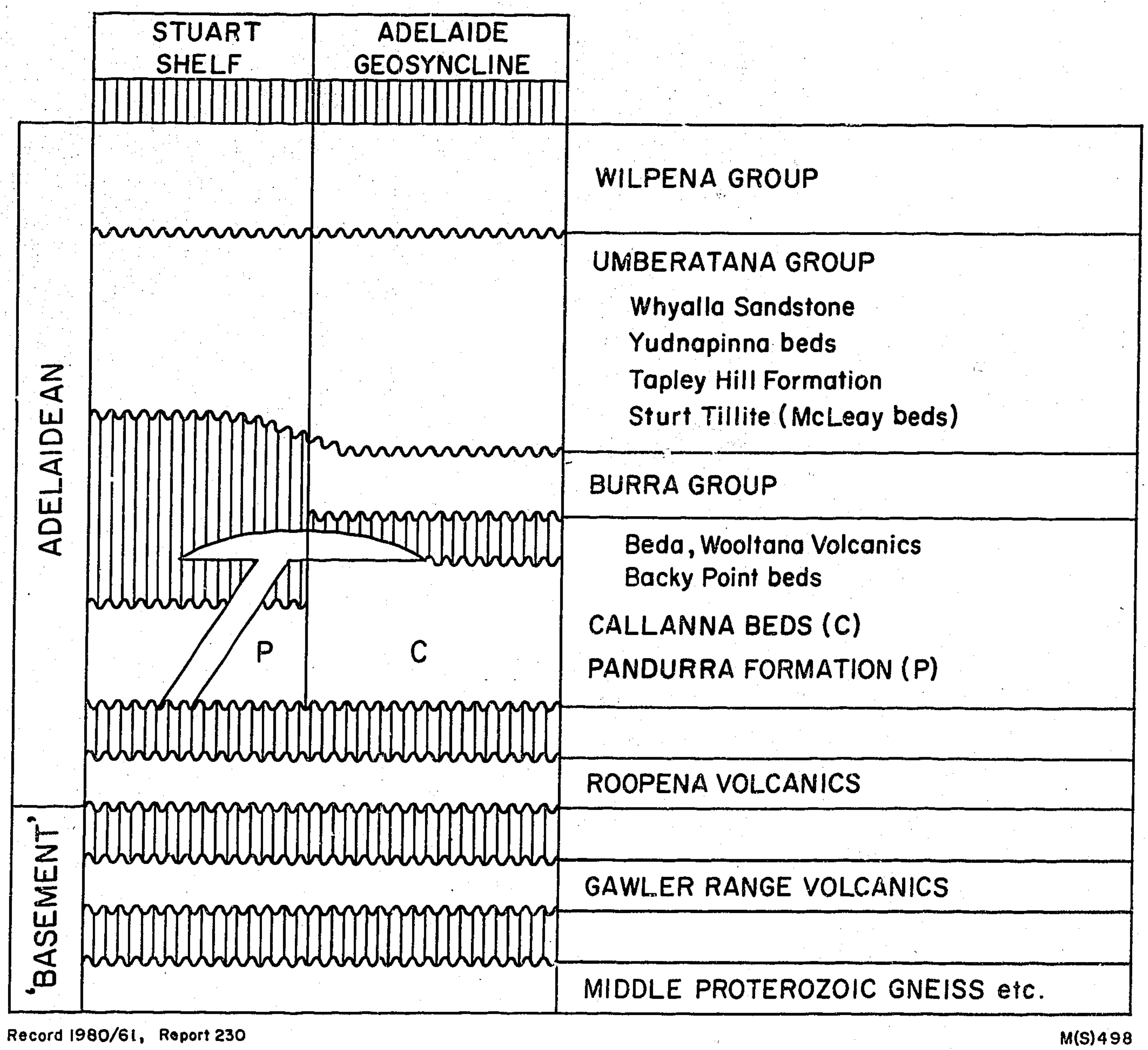

Fig. B12 Stratigraphic columns, Adelaide Geosyncline and Stuart Shelf.

STUART SHELF

In this report we highlight the main conclusions from studies in the Mount Gunson and Lake Dutton areas which were conducted in collaboration with CSR. Three papers discussing the results are in the final stages of preparation.

The main features of the Cattle Grid and related mineralisation in the uppermost Pandurra Formation are:

(i) The discordant nature of the mineralisation within brecciated, silicified, and ferruginised arenite immediately beneath the unconformity between the Pandurra Formation and Whyalla Sandstone.

(ii) The association of topographic highs of Pandurra Formation (the Pernatty Culmination) with faults/lineaments.

(iii) The narrow range of negative $\delta^{34}S$ values for the sulphides, the lack of isotopic equilibration between the various sulphides, and the lack of organic matter within the Pandurra Formation.

(iv) The presence of sulphides stable at low temperatures.

(v) The textural evidence that pyrite replacement accompanied formation of the Cu mineralisation.

(vi) The association of minor Pb, Zn, and Co with Cu and the general lateral zonation from chalcocite-rich ore to bornite-bearing ore with galena and sphalerite.

The mineralisation evidently postdated duricrust formation on the Pandurra arenites. The isotopic compositions indicate that sulphide ions for pyrite formation were most likely formed biogenically under conditions of unlimited sulphate supply, but the lack of organic nutrients indicates this could not have occurred at the sites of mineralisation. Sulphide ions apparently migrated in from above or below, forming pyrite by reaction with oxidised iron in the near-surface zone of the Pandurra Formation. The sulphide could not have been generated during the transgression associated with accumulation of the Tapley Hill Formation (THF) as the pyrite in this unit is isotopically distinct. Therefore, if sulphide ions migrated down into the Pandurra surface, evidence of the reducing conditions that must have accompanied this has not yet been found. This leads us to favour derivation of the sulphide either from reducing, deltaic? mudstone lenses within the Pandurra arenites, or laterally from the Adelaide Geosyncline. Limited sulphur isotope results from the Pandurra mudstone lenses and the Callanna beds of the Geosyncline have indicated that both contain sulphide minerals that are isotopically similar to the Pandurra mineralisation. The high permeability of the Pandurra Formation should have permitted migration of sulphurous fluids over considerable distances, and the fault breccia zone in the Cattle Grid deposit probably resulted in this being a major outflow zone. Fe may have been enriched in the near-surface rocks by previous outflow of Fe^{2+} - bearing groundwaters, or it may have been concentrated during weathering.

Solubility considerations rule out transport of significant amounts of base metals in low-temperature, sulphide-bearing fluids. This accords with textural and isotopic evidence that the Cu mineralisation formed in large part from metalliferous brines reacting at low temperatures with already pyritised Pandurra Formation. The possible metal sources and timing of metal introduction will be discussed after consideration of the THF mineralisation.

The main features of mineralisation within THF in the Mount Gunson area are as follows:

(i) The most significant mineralisation occurs near the base of the THF, but anomalous metal concentrations also occur at the top of this unit.

(ii) The mineralisation is mainly within the more permeable clastic mudstone layers, occurring as disseminated grains, conformable lenses, lithologically constrained veinlets, and fracture coatings. In addition, there are mineralised dolomudstone intraclast layers several metres above the base of the THF.

(iii) There is a zonation from Cu to Pb and Zn inward from both the upper and lower surfaces of THF, and a relatively barren pyrite zone occupies the central portion of some sections.

(iv) There is abundant evidence for replacement of precursor iron sulphide.

(v) The sulphides have a wide range of positive $\delta^{34}S$ values, with a general increase in values upwards in the little mineralised Lake Dutton section; there is a lack of isotopic equilibrium between sulphides.

(vi) The THF mineralisation is mineralogically and geochemically similar to that in the Pandurra Formation.

(vii) There is no evidence for hydrothermal alteration.

(viii) As expected for deposition around a topographic high (Pernatty Culmination), sedimentary structures in the THF near Mount Gunson indicate shallow marginal-marine environments. In the Lake Dutton area, where the THF is not significantly mineralised, there is evidence for deeper-water deposition and the unit is much thicker than at Mount Gunson.

(ix) Significant mineralisation in the THF appears to be localised adjacent to mineralised Pandurra Formation.

The unusual ^{34}S-enriched sulphides in the THF could imply a prolonged episode of bacterial sulphate reduction without replenishment of the sulphate. Biogenic pyrite evidently formed within near-surface reducing muds. Some Cu may have been present during early diagenesis, as evidenced by the irregular Cu sulphide-bearing veinlets which appear to represent early dewatering structures. However, the zoned mineralisation within the THF implies differential precipitation from fluids migrating into this unit. Geochemical similarities and spatial relationships suggest that the fluids which formed the Cu mineralisation in the Pandurra Formation were also responsible for mineralisation in the THF and that these metalliferous fluids appear to have been available, possibly intermittently, over a long period of time. Ascending fluids would have migrated relatively slowly through the THF and would have tended to spread out beneath this unit and along relatively permeable layers within it. The metal zoning at the top of the THF implies that metalliferous fluids also migrated down into this unit from the Whyalla Sandstone aquifer.

There is no shortage of potential metal sources: (i) extensive mineralisation is known in the basement; (ii) basic igneous rocks occur beneath, within, and above the Pandurra Formation; (iii) weathering and erosion of the basement and the mafic rocks should have led to accumulation of labile Cu-bearing phases in the Pandurra Formation. Under intermediate Eh conditions, brines encountering any of these potential source rocks could have dissolved and transported significant amounts of Cu and other base metals.

In summary, it appears that reducing, sulphide-bearing fluids ascended into breccated zones in ferruginised and silicified Pandurra Formation, where pyrite formed. Subsequently, less-reducing Cu-bearing brines ascended through the same permeable zones, reacting with pyrite both in the Pandurra Formation and in relatively permeable silty layers of the THF. Metalliferous brines were available at least until the time of deposition of the Whyalla Sandstone.

The most significant exploration guides in the Mount Gunson region appear to be topographic highs of Pandurra Formation with structure-enhanced permeability. Epigenetic mineral deposits within the uppermost Pandurra Formation is likely to be accompanied by fine-grained mineral deposits within nearby THF. Farther south in the Myall Creek area, topographic relief on the Pandurra Formation appears less important, but permeability remains a major control on the location of mineralisation within the THF.

ADELAIDE GEOSYNCLINE

A stable-isotope study of the Copper Claim area (Fig. B11) is being conducted in collaboration with Utah Development Company. Here, chalcopyrite and iron sulphides occur as fine disseminations and coarser veinlets within low-grade metamorphosed carbonaceous dolomitic arenites and argillites. Palaeogeographic reconstructions by company geologists suggest accumulation of the host sedimentary strata in lagoons, intertidal evaporative environments, and offshore bars.

The results to hand and our preliminary assessments of their implications are summarised below:

(i) Widely varying $\delta^{34}S$ values for the disseminated sulphides, ranging from -18 to +16°/oo (average = -2.7°/oo, σ=9.3°/oo), imply bacterial sulphate reduction under conditions of limited sulphate supply.

(ii) The fact that vein sulphides have $\delta^{34}S$ values within the same range is in accord with their derivation from disseminated sulphides.

(iii) Carbonate in the mineralised sediments has $\delta^{13}C$ values ranging from -4.0 to +2.8°/oo. The more negative values imply incorporation of organically derived CO_2.

(iv) Samples of both bedded and veinlet carbonate have $\delta^{18}O$ (SMOW) values in the range +12.7 to +18.3°/oo, which are significantly lower than values for unaltered marine carbonates. They probably reflect recrystallisation of the carbonates involving groundwaters.

MOUNT PAINTER COMPLEX

Sulphur isotope analyses have been completed on sulphides from brecciated granite and hematite/chlorite breccias. These have $\delta^{34}S$ values between -3.0 and +3.5°/oo, except for a single sample with values close to +8°/oo). Isotopic compositions of barite and carbonate are not yet available.

At this stage, there has been no detailed assessment of these results in the light of other features of this complex. Our preliminary assessment is that the minor pyrite (and the rare molybdenite and chalcopyrite) within fractured, altered granite (sensu lato) could have formed from fluids released during explosive emplacement of granitic magmas. However, the hematitic and chloritic breccias are more difficult to explain. The sulphides analysed from these breccias occur as medium to coarse crystals, whose textural relations remain to be studied in detail. Present indications are that at least some of the sulphide formed after hematite, which largely replaces original magnetite.

LEAD-ISOTOPE TRACER STUDIES OF SOURCES OF METALS IN Pb-Zn DEPOSITS

by

I.B. Lambert

The aim of these studies is to directly assess the sources of metals in the Carboniferous Irish Pb-Zn mines and the Carpentarian McArthur deposit by comparing the Pb-isotope compositions of the ores with those of trace Pb in rocks stratigraphically beneath these sediment-hosted deposits. Potential source rocks must have Pb that is isotopically compatible with the ore Pb. The work was undertaken at the Federal Institute for Geosciences, Hannover, in collaboration with Dr Axel Hohndorf. Final interpretations must await the compilation of further analyses and the following summary is based on a preliminary assessment of the results to hand.

IRISH Pb-Zn DEPOSITS

It appears that:

(i) Galena from Devonian sandstone is Pb-isotopically indistinguishable from galena in Silvermines and Navan ores.

(ii) Syenite from the Navan area has a Pb model age of roughly 400 m.y.

(iii) Trace Pb in host Carboniferous carbonates at Silvermines and Navan is very similar in its isotopic composition to ore galena.

(iv) Pb in <u>residue</u> fractions (after 2N HCl) of Carboniferous carbonates are generally less radiogenic than carbonate from same rocks.

(v) Pre-Carboniferous strata have Pb that varies isotopically from within the ore range to significantly less radiogenic. A red-bed sample from Navan is significantly more radiogenic than the ore.

Unfortunately, these results do not permit unequivocal conclusions concerning ore genesis. They affirm that the ore Pb could have come from leaching of Carboniferous and earlier Palaeozoic strata. However, the data do not rule out the possibility that significant Pb derived from Carboniferous magmatic activity was added to brines circulating within the sedimentary strata.

McARTHUR DEPOSIT

Present indications are that:

(i) The bulk of the carbonate-rich samples have Pb that is much more radiogenic than that in ore galena (after correction of measured present-day results on the assumption that the rocks have remained closed systems to U and Pb since the Middle Proterozoic).

(ii) Residues left after reaction of the rocks with hot 2N HCl (i.e. feldspars, quartz, zircons, some phyllosilicates, etc.) have very radiogenic present-day Pb-isotope ratios. However, when corrected for the concentration of U recovered from these samples, the calculated Pb-isotope ratios at the time of ore formation are impossibly low in some cases. It is obvious that, for these residues, there has been over-correction for the U-supported radiogenic Pb generated since accumulation of the McArthur Group. The reason for this is uncertain at present, but possibilities include U addition since the Proterozoic, radon loss from the sedimentary rocks, or differential leaching of U and Pb during recovery of the metals by acid treatments.

PRECAMBRIAN PALAEOBIOLOGY RESEARCH PROJECT

by

M.R. Walter

STAFF: M.R. Walter and members of the project staff at the University of California, Los Angeles.

This project was undertaken while M.R. Walter was on leave at the University of California in Los Angeles, but received support from the BMR for fieldwork in Australia, and in other ways. Funding from the US National Science Foundation and the National Aeronautics and Space Administration enabled Professor J.W. Schopf of UCLA to assemble in Los Angeles an interdisciplinary team from the USA, Canada, Germany, and Australia, to study for about 1 year the origin and early evolution of life, and its geochemical effects. The project began with fieldwork in Western Australia (Shark Bay, Hamersley Basin, and the Pilbara Block), South Africa, and Canada. From the large collections made at that time and assembled from earlier collections, 400 samples were analysed for their reduced carbon (kerogen) content and carbon isotopic composition, and were searched for microfossils or, in the case of stromatolites, examined for features of biological significance. Using the results of these initial analyses, about 50 samples were selected for detailed chemical analyses of the contained kerogen. For these, the carbon, nitrogen, and hydrogen isotopic compositions were measured, along with the C, H, N, and O contents; the crystallinity of the kerogen was measured by X-ray diffraction; and the colour of the kerogen was recorded. From some of these samples pyrite and organic sulphur fractions were separated and their sulphur isotopic compositions were measured.

In addition to the work on rock samples, organic compounds were synthesised artificially from gas mixtures and with energy sources predicted from models of the early Earth. The compounds were then analysed for the same parameters as the kerogen in an attempt to discover ways to recognise primeval abiogenic organic matter, should it be preserved in the rock record. Two microbiologists in the group worked on theories of bacterial evolution, as far as possible constraining their work with geological as well as biochemical data.

The project proved to be outstandingly successful, and the results are to be published by Princeton University Press as a multi-authored book (the bulk of which has been written). Highlights include the discovery of a much wider range of carbon isotopic compositions among Archaean kerogens than for younger examples. Various interpretations are possible at present, including a more important role for methane-producing bacteria in the Archaean ecosystem, or a greater metabolic diversity at that time which was suppressed by the development of aerobic (oxygen-rich) environments at about 2.5 billion years ago. Significant new microfossil assemblages were found in the Windidda Formation of the Nabberu Basin, the Duck Creek Dolomite of the Ashburton Trough, the Tumbiana Formation of the Hamersley Basin, and the Warrawoona Group of the Pilbara Block. Remarkably well preserved stromatolites of the Fortescue Group (possibly 2.8 billion years old) provided a wealth of biological information and are consistent with the view that oxygen-producing photosynthesis had evolved by that time (in concert with one possible interpretation of the data on kerogen chemistry).

A result that excited considerable interest was the discovery, in co-operation with Professor S.M. Awramik of the University of California at Santa Barbara, of the oldest known convincing bacterial fossils. These were studied in co-operation with Mr R. Buick of the University of Western Australia, whose work in the Pilbara Block, along with that of his colleague Mr J.S.R. Dunlop, had first drawn attention to the palaeobiological significance of the 3.5-billion-year-old rocks of that region. Discovery of the microfossils was preceded by the study of the oldest known stromatolites, also from the same region and discovered by Dunlop.

As a result of this one year of intensive effort, the data base available for interpreting early evolutionary pathways has increased manyfold. Models of early atmospheric and hydrospheric evolution can now be more closely constrained - for instance, a model which has oxygenic photosynthesis evolving during the late Archaean, the atmosphere becoming aerobic soon after, and the hydrosphere becoming aerobic by about 1.7 billion years ago, are consistent with all the available information. By 3.5 billion years ago life had not only originated but diversified into a variety of morphological bacterial forms, some of which were able to perform an advanced metabolic function, the construction of their own cell material from CO_2. Our knowledge of biological history before 3.5 billion years ago is virtually non-existent because even the least metamorphosed older sedimentary rocks have been subjected to amphibolite facies metamorphism (the 3.8 billion year old rocks at Isua, in Greenland).

PRECAMBRIAN SULPHUR ISOTOPES AND A POSSIBLE ROLE FOR SULPHITE IN THE EVOLUTION OF BIOLOGICAL SULPHATE REDUCTION

by

G.W. Skyring & T.H. Donnelly

The aim of this study is to re-examine the sulphur isotope compositions of Precambrian sulphides and sulphates in relation to the evolution of the pathways of sulphate reduction in procaryotes. This work is currently being written up for publication. It has resulted in the following suggestions:

1. Sulphite could have been a small but significant and persistent component of Archaean seas (isotope data).
2. Sulphite and not sulphide (or sulphate) was the major sulphur source for procaryotes evolving in the Archaean.
3. As the atmosphere and hydrosphere became oxygenic, iron sulphide sediments were oxidised to iron oxides (remaining as sediments) and sulphate (which dissolved in the seas).
4. As the process of oxygenation continued, the persistence of hydrothermal or volcanogenic sulphite decreased as sulphite was oxidised to sulphate.
5. As sulphite (and sulphide) became limiting to evolving procaryotes there occurred a selective pressure which resulted in the evolution of a biochemical mechanism for sulphate reduction.
6. As the concentration of sulphate increased in the seas, the effects of dissimilatory sulphate reduction on sulphur isotope fractionation become globally significant.
7. As sulphate became ubiquitous and concentrated in the seas, its effect on the geochemistry of hydrothermal reactions occurring in the crust became evident. Finally sea-water sulphate became the major sulphur component of crustal hydrothermal and volcanic reactions.

8. A combination of the global biological cycling of sulphur, particularly dissimilatory sulphate reduction, and the physical cycling of sulphate through seas and crust, resulted in sulphur isotope distribution patterns, which for both sulphides and sulphates are quite different from those before around 2.0 billion years ago.

SIMULATED SEDIMENTARY STUDIES

by

B. Bubela

STAFF: B. Bubela, G. Jemmett, C. Robison

The objectives of the simulated sedimentary system and the results for the previous 12 months have been described in detail in the last Annual Summary. Since then the studies concentrated on diagenetic processes affecting the organic matter in the sediments.

As reported previously, organic matter isolated from the individual strata of the sediments was separated into hydrocarbons, alcohols, and organic acids. The following changes due to diagenetic processes were observed in the isolates.

ORGANIC LAYER

HYDROCARBONS AND ALCOHOLS

The original algal material as buried in the sediments was rich in heptane and heptadecanol as expected from its algal origin. During the diagenesis the alcohol was preferentially removed and the hydrocarbon became more significant. A mixture of unidentifiable hydrocarbons encountered frequently in immature crude oil formed in the second year of the experiment. Hydrocarbons and alcohols in the C_{23}-C_{25} accumulated and the hydrocarbon range extended into the C_{30} region. This is being taken as evidence that a substantial part of the originally algal biomass has been reworked and that the organic matter is now predominantly of bacterial origin.

ORGANIC ACIDS

The overall concentration of organic acids increased during diagenesis. Previously undetected phthalic acids occurred in considerable quantities. We have observed phthalic acids produced as a result of heavy metal stresses on some bacterial cells. The pathways leading to the formation of the acids is not known, but they may be formed by condensation of maleic acid and butadiene a material previously described by us as being formed by microbiological action in sediments.

ARAGONITE LAYER

HYDROCARBONS AND ALCOHOLS

The original material contained only traces of hydrocarbons and alcohols. During the experiment organic matter accumulated in this layer showed a predominance of C_{20} material, indicating its bacterial origin.

ORGANIC ACIDS

C_{16} organic acids were observed in the original material. Similarly to the organic layers, phthalic acids appeared in the sediment at the late stage of the diagenesis.

HIGH-MAGNESIUM CALCITE LAYER

HYDROCARBONS AND ALCOHOLS

Only traces of hydrocarbons and alcohols were detected in the original material. At a later stage of diagenesis odd-even predominance was established in the formed C_{21-23} hydrocarbons. A pattern of hydrocarbons similar to that formed in immature crude oil was detected.

ORGANIC ACIDS

The original material shows a typical C_{16} predominance, characteristic of marine algae. During diagenesis this material decreased in concentration, and C_{20-25} became predominant, indicating the formation of bacterial biomass. Phthalic acid again became detectable.

SAND LAYER

The original material was free of organic matter in extractable quantities.

HYDROCARBONS AND ALCOHOLS

During the early stages of the experiment C_{18-19} hydrocarbons appeared in the sediments. At a later stage a C_{20-25} predominance of bacterial material was established. At the conclusion of the experiment the secondary biomass was considerably reduced in concentration.

ORGANIC ACIDS

Organic acids with C_{20-22} predominance were established at the end of 18 months and the C-distribution and concentration became static.

It is evident that buried organic matter retains its characteristics related to its algal origin for a relatively short time in biologically active environments. Some of the components of the original biomass may be transported through the sediments serving eventually as a substrate for the formation of bacterial biomass.

The organic material which has changed as described under anaerobic conditions at the temperature range of 15-25°C was exposed for 6 months to environmental conditions of 65°C in an anaerobic environment. The material is being analysed in the manner described above. A part of the material that has undergone the secondary diagenetic processes is being exposed anaerobically to temperatures of 65°C and pressure of 20 000 kPa.

It is hoped that by studying organic matter which has been passed through sequences of environmental conditions a better understanding of diagenetic pathways involving organic matter will be obtained.

MICROBIOLOGICALLY ENHANCED OIL RECOVERY

by

B. Bubela

STAFF: B. Bubela, C. James, C. Manning, V. Partridge.

The investigation of the feasibility of microbiologically enhanced oil recovery is being supported by a grant made under the National Energy Research Development and Demonstration Program.

At the early stage of the program the investigation was concentrated on developing techniques and instrumentation required for the project.

a) An apparatus designed by the laboratory capable of growing micro-organisms under reservoir conditions (20 000 kPa and temperatures up to 150°C) was constructed, tested, and passed for safety by the Department of Works, NSW. It has been installed in the laboratory and it is now being prepared for experimental runs.

b) A simple simulated reservoir system was developed for fast evaluation of certain parameters (viscosity, surface tension, porosity, and permeability) involved in microbiologically enhanced oil recovery.

Experimental results so far indicate:

1. Microbiologically enhanced recovery of oil in a simulated oil-wetted system increased the yield of oil from 6 to 48%.

2. Since microbiologically produced CO_2 in the reservoir may affect the porosity and permeability of the reservoir rock, the effect of biologically produced CO_2 in a microbiologically active environment on the porosity and permeability of calcite and of dolomite are being investigated. Results obtained so far show that the porosity of a given sample of dolomite increased from 24 to 25% and that of calcite from 17 to 45%. The permeability increased from 2D to 14D and from 2D to 47D for the dolomite and calcite respectively. These results indicate one possible effect of biologically produced CO_2 on the reservoir.

The following further aspects of the project are being investigated.

1. The effect of microbiological action under simulated reservoir conditions on the crude oil composition. The results in hand are too preliminary to be conclusive.

2. Scale-down simulation experiments verifying field reports as described overseas are being conducted to evaluate the significance of such results to our project.

3. The significance of bacterial growth in the presence/absence of crude oil as related to the microbiological production of surfactants.

4. The effect of oil-wetted reservoir as to the water-wetted reservoir on microbiologically enhanced oil recovery.

5. The effect of the sweeping velocity on the recovery, the oil-characteristics, and the temperature effect.

6. An extensive literature survey was made of physico-chemical parameters relevant to the microbiologically enhanced recovery. It will provide the necessary basic information required for the understanding of the processes involved. It is intended to publish the results of this survey as a review in an appropriate journal.

CONFERENCE AND OTHER ACTIVITIES

The following conferences were attended by members of the Baas Becking Laboratory

- Dahlem Conference on "Biospheric Evolution and Precambrian Metallogeny", West Berlin, September: P.A. Trudinger, M.R. Walter.
- 2nd International Symposium on Microbial Ecology, Warwick, U.K., September: J. Bauld, P.A. Trudinger.
- Joint meeting of the Australian and New Zealand Societies for Microbiology, Dunedin, May: J. Bauld, G.W. Skyring.
- Australian Society for Mycology and Aquatic Biology, Inaugural Meeting, Melbourne, May: J. Bauld.
- 4th Australian Biotechnology Conference, Melbourne, August: B. Bubela.
- 4th Australian Geological Convention, Hobart, January: R.V. Burne.
- 2nd International Archaean Symposium, Perth, May: M.R. Walter.
- Precambrian Paleobiology Research Group, Symposium on 'Interdisciplinary Studies on the Origin and Evolution of Earth's Earliest Biosphere', Los Angeles, August: J. Bauld, M.R. Walter.

During May-June, L.A. Plumb presented aspects of the Laboratory's research in discussions with members of the Institute of Microbiology and the Institute of Geology, Academia Sinica, while in Peking as an accompanying member of the QINGHAI-XIZANG (Tibet) Plateau Symposium. The meeting was followed by the First International Scientific Expedition to the Tibet Plateau.

In February, Dr. I.B. Lambert presented an invited lecture on the genesis of Pb-Zn deposits at the Symposium at the University of Heidelberg in honour of the 90th birthday of Professor Paul Ramdohr. Whilst in Europe, he also lectured at Billiton Exploration in The Hague, and at the Universities of

Bochum, Cologne, Innsbruck, Utrecht and Zurich. He visited mines in Austria, France, Ireland, and Germany.

In August, aspects of the Laboratory's work, particularly those relating to modern sedimentary environments, were presented by J. Bauld during informal seminars at Indiana University and the University of Wisconsin-Madison, USA.

In May, B. Bubela presented a paper in Adelaide on 'The involvement of microbiological processes in ore-leaching, enhanced oil recovery and oil-shale pre-treatment' to the joint session of industry representatives, Senate Committee, the CSIRO Executive, and the Department of Science.

IRIAN JAYA GEOLOGICAL MAPPING PROJECT

Project Manager: D.B. Dow

IRIAN JAYA GEOLOGICAL MAPPING PROJECT

by

D.B. Dow

INTRODUCTION

BMR is the managing agent for the Irian Jaya Geological Mapping Project, an Australian Colombo Plan aid project in which the main aim is to assist Indonesia in developing modern geological and geophysical surveying techniques suitable for the mountainous jungle-covered terrain that constitutes a large proportion of Indonesia's land area. Thus it is predominantly a training project in which training in logistics and organisation of field operations is as important as training in the technical aspects.

The geological mapping of Irian Jaya (the western half of the island of New Guinea) was chosen as a suitable project, partly because it provides training in a wide range of terrains and poses enormous difficulties of access, but also because its geology and mineral potential is so poorly known. Consequently a second, and equally important, objective of the project is to map the geology and undertake a regional gravity survey of the province. A systematic stream-sediment geochemical and panning survey is being carried out concurrently with the geological mapping to enable a proper mineral assessment to be made.

The work is being done jointly with the Geological Research and Development Centre (GRDC), a Directorate of the Indonesian Department of Mining and Energy. The main contributions from Australia are the professional and technical personnel, the equipment, and the charter of helicopters which are the principal means of transport to gain access to the interior.

The project is based at GRDC headquarters in Bandung, the capital of West Java which is located 180 km by road from Jakarta. All project personnel live in Bandung, which is a large predominantly government city and provides very pleasant living conditions. Office space provided by GRDC is at present insufficient for all project members, so until the new GRDC building is completed in 1982 some members are accommodated in offices rented by the Project.

Fieldwork (geological and geophysical) occupies 6 months of each year for two years out of three. The third year will be used to catch up on the backlog of compilation and report-writing accumulated as a result of such long field seasons. It would be preferable to have shorter field seasons but helicopter companies in Indonesia are not prepared to submit realistic tenders for less than 6 months work in such a remote region.

The project commenced in October 1978 with the start of geological mapping in Kepala Burung (the 'Birds Head' - Fig. J1). The first geological field season occupied only 3 months but has since been followed by two $4\frac{1}{2}$-month field seasons in 1979 and 1980 each of which are broken into two 9 - 10 week sessions separated by a 6-7 week break over the religious festival of Lebaran. During these breaks the helicopters have been utilised by the geophysical group.

STAFF

The Project staff are listed in Table J1.

Essential administrative support in Canberra is provided by: BMR finance section, Departmental headquarters staff, and the Fyshwick stores group.

FIELD OPERATIONS

Fieldwork is carried out from base-camps located at convenient supply centres. Manokwari, Nabire, and Enarotali (Fig. J2) have been used so far; in future, Jayapura and Wamena will also be used. Temporary fly-camps are used to map areas more than 100 km from the base-camps, and these have been set up by using, at various times, local coastal ships, powered canoes, the Project's two river trucks, fixed-wing aircraft chartered by GRDC, and the two helicopters chartered by the Project. Logistical support poses problems in most places in Indonesia, but at the extreme end of supply lines such as Irian Jaya, the problems assume daunting proportions. Nevertheless field operations have been maintained without serious interruption during the two years that the Project has been operating.

Geological mapping is done mainly by ground traverses ranging in duration from one to seven days or even more, though three-to-five-day traverses are most common. In some areas, spot observations made at sporadic helicopter landing sites are used to fill in the geology but in few places do they constitute the main mapping method. The geophysical gravity observations, on the other hand, are made almost exclusively at natural helicopter-landing sites, though, in more inaccessible country, helicopter pads cut by geologists from the jungle at the end of a traverse have provided the only access.

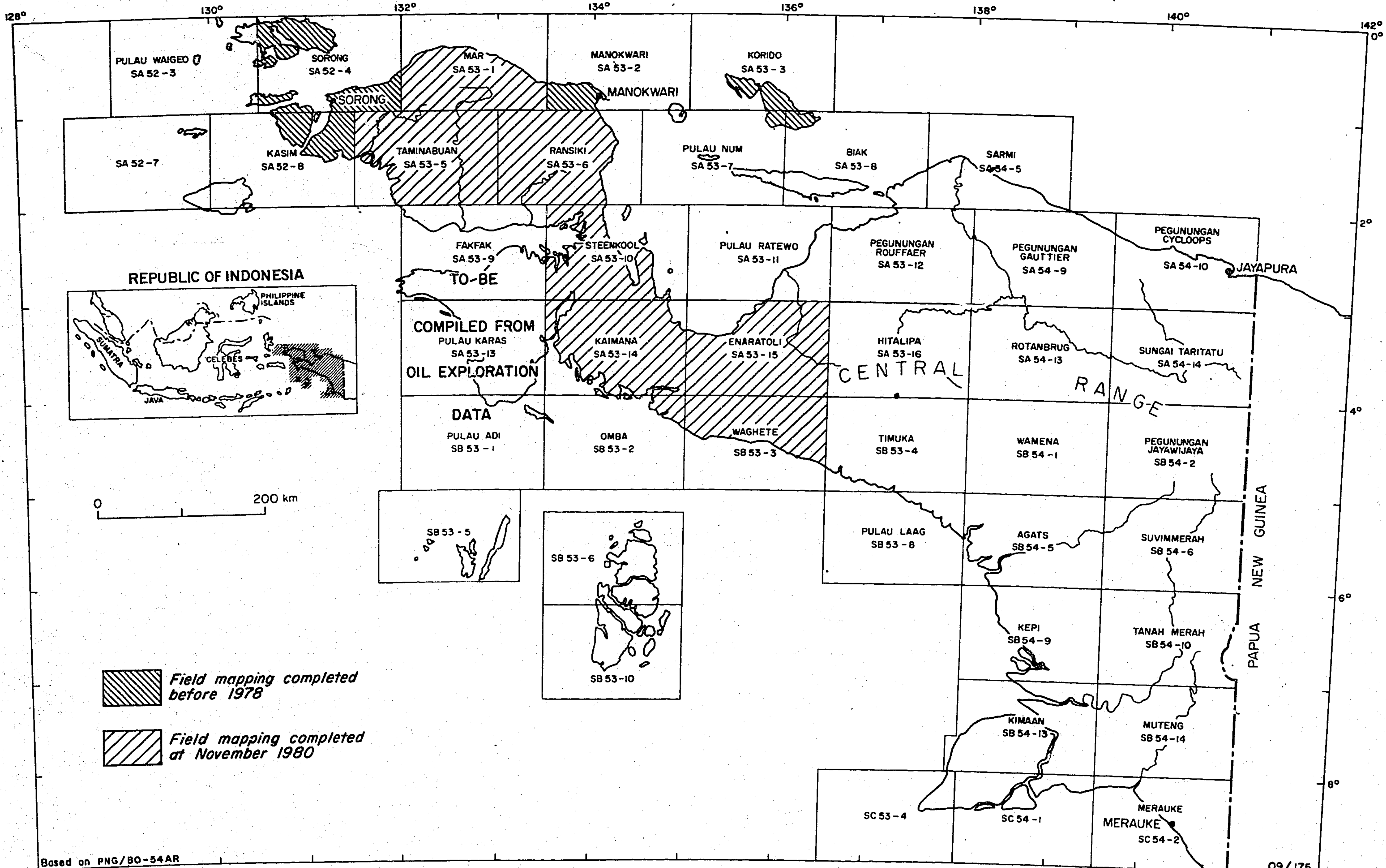

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Fig. J1 Geological mapping, Irian Jaya.

TABLE J1

IRIAN JAYA PROJECT STAFF

	AUSTRALIAN		INDONESIAN	
	NAME	TITLE	NAME	TITLE
GEOLOGICAL	D.B. Dow	Project Co-manager	R. Sukamto	Project Co-manager
	D.S. Trail	Supervising Geologist	Nana Ratman	Project Leader
	P.E. Pieters	Group Leader	Sumitra Atmawinata	Geologist
	R.J. Ryburn	Group Leader	Udi Hartono	Geologist
	C.J. Pigram	Group Leader	Aang Achdan	Geologist
	G.A. Robinson	Geologist Instructor	Sahat L. Tobing	Asst. Geologist
			Bhakti H. Harahap	Asst. Geologist
			Ukat Sukanta	Asst. Geologist
			Chairul Amri	Asst. Geologist
			A. Sufni Hakim	Asst. Geologist
			Hermes Panggabean	Asst. Geologist
			Endang Suryana	Draftsman
			Philips Waromi	Draftsman
GEOPHYSICAL	B.C. Barlow	Project Geophysicist	G.S. Akil	Project Leader
	G.E. Duck	Geophysical Technical Officer	Sutisna Sukardi	Senior Geophysicist
			Mohamad Untung	Senior Geophysicist
			Juniar Pardemahan H.	Junior Geophysicist
			Sardjono	Junior Geophysicist
			Marzuki Sani	Junior Geophysicist
			Imam Margono	Junior Geophysicist
			Warsono A.P.	Technical Officer

ADMINISTRATIVE	NAME	TITLE
	G.A. Dunn	Administrative Officer
	A. Sasmita	Accounts Clerk
	N. Rochendi	Secretary
	I. Lukman	Secretary/Receptionist
	T. Madjid	Typist/Clerk
	Harli S.	Counterpart Liaison
	D. Priyatno	Maintenance Officer
	Maxie Johannes	Head Driver
	Nana S.	Driver
	Yayat	Driver
	Iskandar	Driver
	Wahyu	Driver
	Leo Sambas	Driver

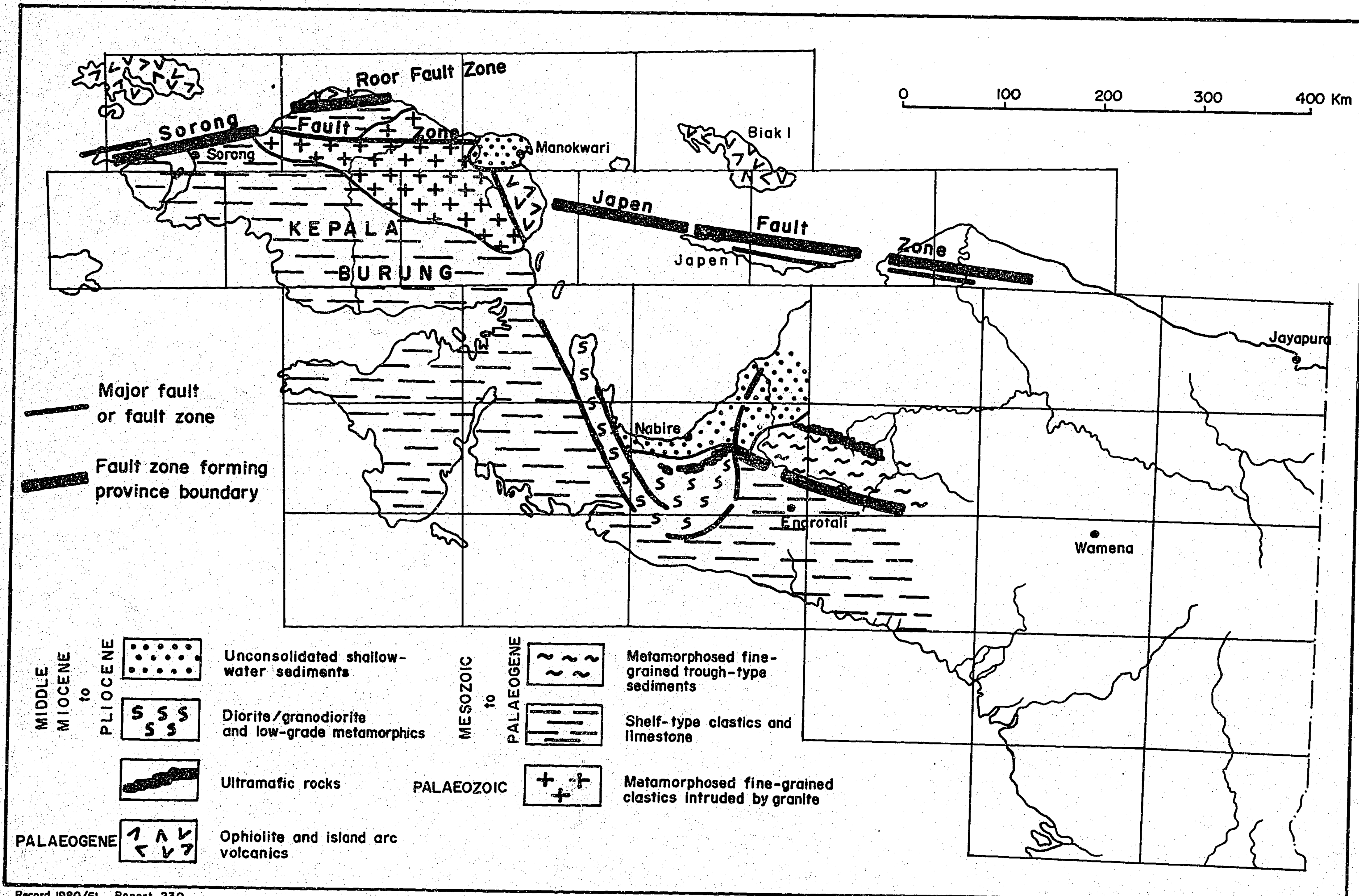

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Fig. J2 Geological sketch map, western Irian Jaya

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Ground geological traverses are generally made along rivers where the rocks are best exposed. Because several nights are spent in the jungle, all equipment and food must be carried. A traverse party therefore consists of one or two geologists and between three and six local porters. At the end of the traverse the party is picked up by helicopter at a predetermined locality which is generally a natural clearing such as a gravel bar in a river, but in difficult areas a landing pad may have to be cut from the jungle.

Traverse conditions in Kepala Burung have in most places been unpleasant. The country is generally less than 800 m above sea level and, in addition to providing hot steamy conditions in which fungal and other infections trouble most geologists, it harbours a wide range of snakes, biting insects, and stinging plants. The climate is wet and even small side-streams carry a large volume of water. Not only is wading chest deep a common necessity, but even minor gorges are impassable and require hours of laborious cutting through jungle to climb around. Stream boulders are commonly covered in algal slime and in places are devastatingly slippery, and make travel slow and at times dangerous.

The hazards faced by the geologists are exemplified by day traverses undertaken by three geologists south of Nabire. Torrential rain started much earlier than usual (before midday) and shortly afterward reached such intensity that the traverses had to be cut short and the geologists started returning to the pick-up point. However, the rivers they were traversing had swollen to such an extent that the return was difficult and dangerous. Low obscuring cloud prevented the helicopter reaching the geologists in the afternoon, an eventuality normally covered by survival packs left at the pick-up points. Unfortunately the unprecedentedly high flood in the river had carried one pack downstream and had inundated and soaked one other. A very unpleasant night thus resulted for two of the three geologists, one of whom was so badly bitten by mosquitoes that subsequent infection of the bites put him out of action for several days.

Despite these problems traverses have been carried out at the high density necessary to elucidate the geology of such a complex area.

Transport between geophysical observation points is generally by helicopter, fast interval times being necessary to reduce errors, particularly in barometric levelling. Many of the problems which plague the geologists on foot traverses have a much lesser effect on the geophysicists, whose main problems are photonavigation on complex loop flights with frequent landings at difficult sites. The climate and operating conditions are such that it is difficult to maintain serviceability of the delicate geophysical instruments.

In some areas it has been impossible to achieve a 10-km grid of observation points because landings were impossible. So far these areas have been restricted in extent and have not detracted from the value of the geophysical mapping.

More detailed traverses have been observed in some localities to give more detailed profiles across important gravity gradients detected by the regular grid coverage. Helicopters and river trucks have been used for such profiles along beaches to establish stations for which the elevations and hence the gravity anomalies can be determined to higher accuracy.

GEOLOGICAL PROGRESS

FIELD MAPPING

Despite the difficulties of working in such a remote area in a developing country, the geological surveys have kept to the initial, somewhat optimistic, field schedule. The original schedule was optimistic in that it took insufficient account of the time taken to train Indonesian counterparts and to establish routine field procedures. These factors were partly offset by work which the Shell Oil Company did before independece and which has been incorporated into the Project results. Mapping completed to the end of 1980 is shown in Figure J1.

DATA STORAGE, COMPILATION, AND REPORT WRITING

The amount of time available for these essential tasks has been completely inadequate to deal with the 15-months fieldwork completed to date. Thus only 12 months total has been available between field seasons, and much of this time has been spent by the Australian staff transferring to Bandung from Canberra. The situation has been exacerbated by the fact that administrative and other duties have occupied a considerable proportion of the Indonesian counterparts' time in Bandung.

Most of the time available has therefore been directed towards systematically recording the huge amount of data collected by 15 geologists during 15 months of intensive mapping. The task was a formidable one, especially as many of the counterparts' command of English leaves much to be desired, and in any case all their field notes are written in Indonesian. The problem has been overcome by re-writing all field notes on to standardised field data sheets, and recording the data on Hewlett Packard data cartridges for use in the Project's computer system of data storage and retrieval.

GEOPHYSICAL PROGRESS

by

B.C. Barlow

FIELD MAPPING

Mapping completed to October 1980 is shown in Figure J3, and is virtually up to schedule in spite of major problems caused by delays in the shipping of fuel and by helicopter unserviceability.

It was necessary to repeat an area near Manokwari because data gathered during 1979 was destroyed in a helicopter crash on 1 October 1979.

Coverage in the Steenkool and Kaimana Sheet areas was better than anticipated, but involved a large number of somewhat hazardous landings. Readings were obtained on all offshore islands and reefs using a float-equipped helicopter.

DATA STORAGE, COMPILATION, AND REPORT WRITING

Data from the 1978 and 1979 field seasons were computed on the Cyber 76 computer in Canberra but could not be finalised because of data lost in the helicopter crash. A large number of errors detected during computing were subsequently corrected in Bandung. The error rate was higher than normal because the field techniques were new to most counterpart personnel.

During session 1 of the 1980 field season the field crew was increased in number, and there were two periods when little or no flying was possible because of lack of fuel or helicopter unserviceability. These factors combined to give more time for flight preparation, checking of data, and calculation and mapping of preliminary results in the field. The error rate is much improved compared with 1979 and such errors as were made could be corrected more rapidly in the field.

Calculations in the field are made using reasonably powerful programs on a Hewlett Packard 97 Calculator but the results cannot be finalised without computer processing to remove loop closure errors by least-square adjustment and other refinements.

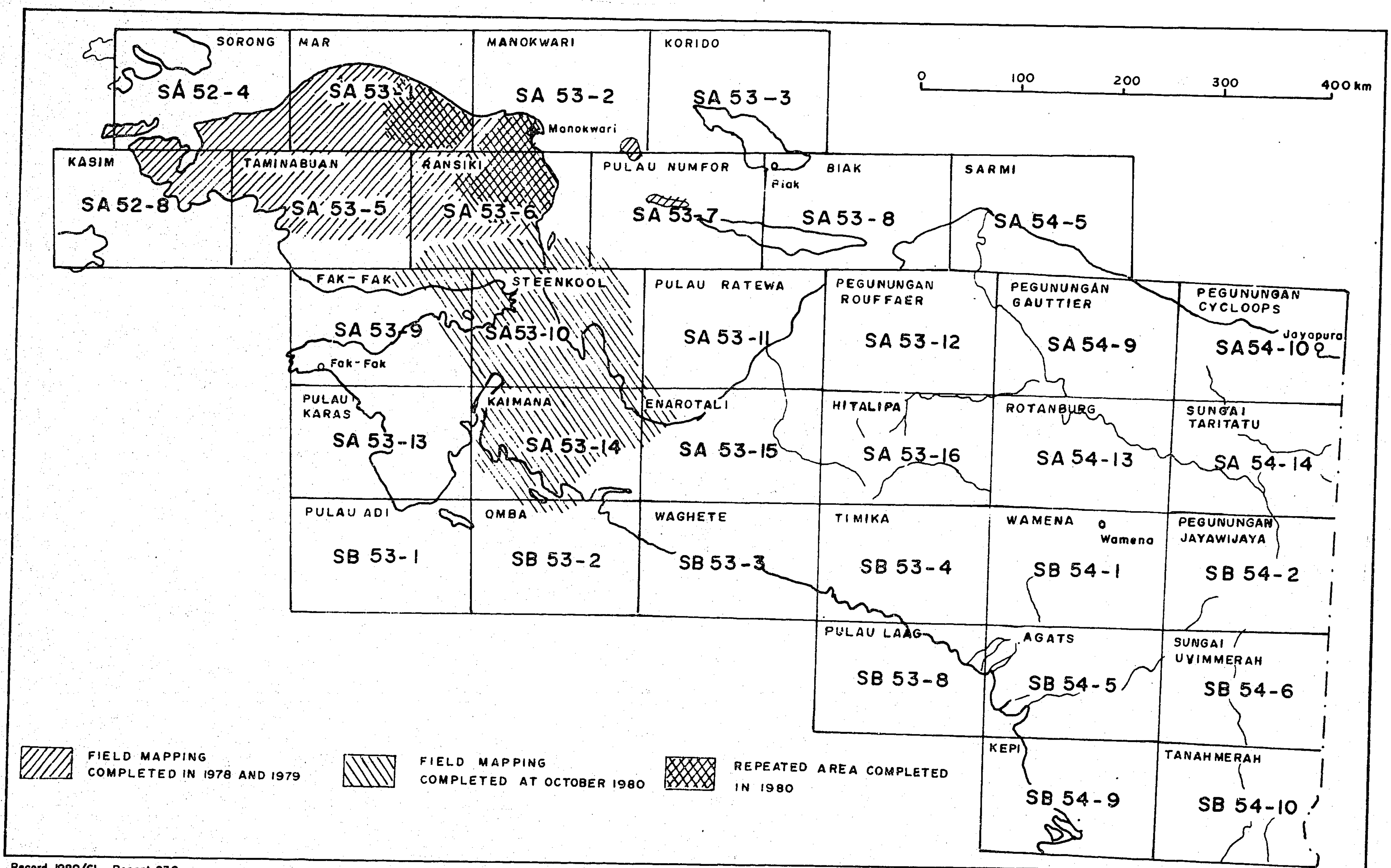

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Fig. J3 Geophysical mapping, Irian Jaya.

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It is planned to produce preliminary Bouguer anomaly maps in step with the production of preliminary geological maps at scales of 1:250 000 and smaller.

Gravity data obtained during the Project have been used in two papers presented at scientific meetings in Indonesia.

RESULTS

GEOLOGY by D.B. Dow

At the start of the Project the geology of Kepala Burung was fairly well known as result of oil exploration work done before independence, and over most of the region the present mapping done by the Project up to the end of 1979 had done little more than add detail to areas, especially those that were sketchily known.

The work done during the 1980 field season was the first in a virtually unknown area: the area where the north-westerly-trending structures of the 'birds neck' joined with the east-west structures of the 'body', or mainland. As expected, the geology has proved to be very complex and has proved difficult to elucidate because most of the area is of low relief and covered by dense tropical jungle. Exposures are confined to streams and are commonly of highly weathered rock. Conversely, the rest of the area has good outcrops on the flanks of Weylandt Range but because it rises precipitously to over 3700 m, most of the outcrops are inaccessible. Nevertheless, the area was mapped in sufficient detail to ascertain the main geological features.

The region is divided into three areas of contrasting geology: the western third in which the northwesterly trending structure of the neck predominate; the eastern third in which the structure is mainly east-west, parallel to the main Central Range; and the central area which consists of a plutonic and metamorphic complex overlain to the north by Pliocene sediments.

Western region

The neck region consists of tightly folded Mesozoic and Palaeogene platform sediments overlying a fragment of Australian continental crust. The folds have horizontal axes which trend northwest, and are markedly asymmetric with the southwestern limbs of the anticlines, which are commonly overturned and broken by thrust-faults.

The platform sediments exposed in the cores of the anticlines belong to the Triassic/Jurassic Tipuma Formation, which consists of over 1500 m of greenish grey clastics and red and green claystone and siltstone. The overlying Kembelangan Formation consists of over 2000 m of dark fine-grained clastics and interbedded quartz sandstone. These in turn are overlain by the New Guinea Limestone group, a sequence of limestone and subordinate marl between 1500 m and 2000 m thick, which ranges in age from Paleocene to middle Miocene.

Palaeozoic metamorphics and intruding granites underlie the platform sediments to the north, in the middle of Kepala Burung, but they are not exposed in the neck area.

The eastern margin of the neck consists of a series of straight faults with marked topographic expression which constitute the Wandamen Fault Zone. The faults are marked by wide zones of intense shearing in which the platform sediments are steeply dipping and in places overturned or isoclinally folded.

Eastern region

The eastern region consists, in the south, of platform sediments identical with those of the western region. The sediments are folded into symmetrical whaleback anticlines which have horizontal axes and are separated - not by similar synclines, but - by narrow zones of vertical strata.

The platform sediments are assumed to be underlain by Australian continental crust and their northern limit is a major fault zone which trends slightly north of west, along the northern fall of the main range.

To the north of this fault zone the rocks are metamorphosed fine-grained sedimentary rocks (now mainly dark sericite schist) with lenses of green metavolcanics. The rocks are assumed to be of trough-type sediments which accumulated along the northern edge of the Australian continent during Mesozoic and possibly Palaeogene times. These metamorphics are bounded on the north by a thick belt of ultramafic rocks, and on the west by a sinuous fault.

Central zone

The central region, where the neck joins the body, consists of an igneous/metamorphic complex on the south overlain by shallow-water Pliocene sediments to the north.

It has been a surprise to find that the complex is of Neogene age and therefore much younger than other metamorphic complexes known in the island of

New Guinea. The complex consists of a large batholith of diorite/granodiorite of middle Miocene age; this intrudes metamorphics which are now predominantly quartz sericite schist but were originally probably the Mesozoic and Tertiary platform sediments of the Australian continent. The middle Miocene granitic rocks are also considerably affected in places by the regional metamorphism, which must therefore be post-middle Miocene. This rather startling conclusion is supported by K/Ar isotopic age determinations of 2.1 m.y. and 5.1. m.y. for boulders of metamorphics from streams draining the complex.

Later diorite intrusives approaching batholithic proportions intrude the metamorphics to the south. These give isotopic ages in the range 2.07 m.y. to 4.12 m.y., and therefore were probably syntectonic.

The western limit of the complex is the Wandamen Fault Zone, and the southern and eastern limits are marked by a sinuous fault, which like all the other major faults of the region has a prominent physiographic expression.

Though they are not seen in contact, the sediments north of the complex are younger than the complex: at many places the base of the succession consists of a polymict conglomerate which contains clasts of all the rocks found in the complex. Foraminifera in the sediments give the age only as Pliocene, but they are unlikely to be older than late Pliocene.

ECONOMIC GEOLOGY

In other regions of the island of New Guinea, including the Ertsberg region in Irian Jaya, similar Pliocene magmatic activity has been accompanied by deposition and concentration of metalliferous minerals to form economic deposits of copper and gold, so it has been a major disappointment to find that the igneous rocks in the Enarotali Sheet area appear to be almost completely barren. This initial observation must await confirmation by means of the analysis of stream sediments and panned samples from the Sheet area, but the main indicator of mineralisation, widespread hydrothermal alteration of the rocks, is conspicuously lacking. Another indicator of mineralisation is the presence of alluvial gold in streams draining the igneous rocks but, apart from the gold south of Nabire discussed later, and sporadic traces in streams draining Weylandt Range, no gold has been discovered.

The reason for the lack of mineralisation is not obvious, but in other parts of New Guinea the igneous activity was not accompanied by metamorphism, so in the Enarotali area the conditions which caused the metamorphism could have inhibited the mineralising processes.

The Tertiary sedimentary rocks are regarded as having poor prospects for metalliferous mineralisation, so it was a surprise when routine panning of the streams draining the mountains immediately southeast of Nabire showed traces of gold. One of the streams, which runs through the town, contains reasonable prospects in the headwaters which could be good enough to provide a much-needed small local industry. Towards the end of the field season these gravels will be tested, and so will the extensive gravels downstream, which also contain gold and offer some prospect of exploitation on a larger scale.

The origin of the gold is not known and this will be investigated at the same time. At present there are two possibilities:

(a) The gold is derived from the younger Tertiary conglomerate which contains a wide variety of igneous and metamorphic rocks. The gold, however, is not as well flattened as is usual with gold derived from conglomerates.

(b) The gold-bearing rivers drain an inlier of Pliocene volcanic rocks which has been exposed from under the younger Tertiary sediments. It seems more likely that the gold originated in these rocks.

Though the region does not appear to offer good mineral potential, it does have two good sites for hydroelectric stations which could be of great value as the region develops.

(a) Twenty-five km south of Nabire, rivers draining a large high-rainfall area break through a narrow gorge which appears to be an ideal site for a dam that would impound a lake over a large area of swampy uninhabited country. The hydrostatic head of the dam could be increased by taking advantage of the steep gradient of the river downstream in the gorge.

First indications therefore are that hydroelectric power sufficient for any projected growth of Nabire township could be otbained by a relatively modest investment. As Nabire is to be the gateway into the highlands of Irian Jaya, the potential of this hydroelectric scheme should be investigated. As a very preliminary step the Project investigated the geology of the damsite and the gorge downstream. The rocks are highly indurated metavolcanics which, although highly jointed, would probably provide good abutments for a dam.

(b) There is an even more favourable site for a hydroelectric power station at the northern end of Lake Paniai. The lake is situated near Enarotali and is about 1730 m above sea level; at its northern extremity there is a low saddle less than 5 m above lake level which drops steeply to a tributary of the Siriwo River. The lake water could be tapped by a siphon and dropped down the tributary giving a total available hydrostatic head of at least

600 m. As the inflow into the lake is considerable the potential power output is very great, and would have the added advantage of being able to be increased as required by repeating the initial siphon. The lake is large and offers a huge natural storage which should cope with any foreseeable rainfall flucatuations.

There is little likelihood of power stations being constructed on these sites in the near future, nevertheless with the world demand for energy growing so rapidly, there is little doubt that they will eventually be built.

GEOPHYSICS

Preliminary Bouguer anomaly contours for the areas surveyed in 1978, 1979, and 1980 (up to October) are shown in Figure J4.

The broad gravity gradient across the top of Kepala Burung remains unchanged by the additional data obtained in 1980. This gradient is the gravity expression of the complex Sorong Fault Zone. A Bouguer anomaly high of +178 mGal in the extreme north of Kepala Burung is indicative of oceanic crust but is limited in area. The gravity expression of the Ransiki Fault is a NNW-SSE gradient passing through Ransiki which was clearly shown in earlier preliminary maps. Supplementary data obtained during 1980 in the Arfak Mountains show that the gravity picture is complicated by high-density material under the mountains. The picture should become clearer when mathematically complex terrain corrections have been calculated for stations in mountainous terrain.

A deep gravity low with Bouguer anomaly values as low as -88 mGal at the eastern end of Bintuni Bay indicates the thick sedimentary section of the Bintuni Basin. The deepest part of the gravity low (and the basin) is roughly circular in shape, but the gravity low extends at smaller amplitude (-25 mGal) for more than 100 km to the SSE, indicating a 'synclinal' extension to the basin in that direction.

The southwestern side of that extended low is bounded by a gentle gravity gradient, Bouguer anomaly values rising to +60 mGal at the coast near Kaimana. This gradient is the expression of tectonic structure at depth; only a small part of the gradient is caused by thinning of the near-surface sediments. The gravity picture shows that tectonic structure at depth under the 'crop' of Kepala Burung has the same NNW-SSE strike as the surface structures and geomorphology. This is important because in other areas, obvious surface geology is not necessarily related to structure at depth, from which it is dissociated by a mobile layer.

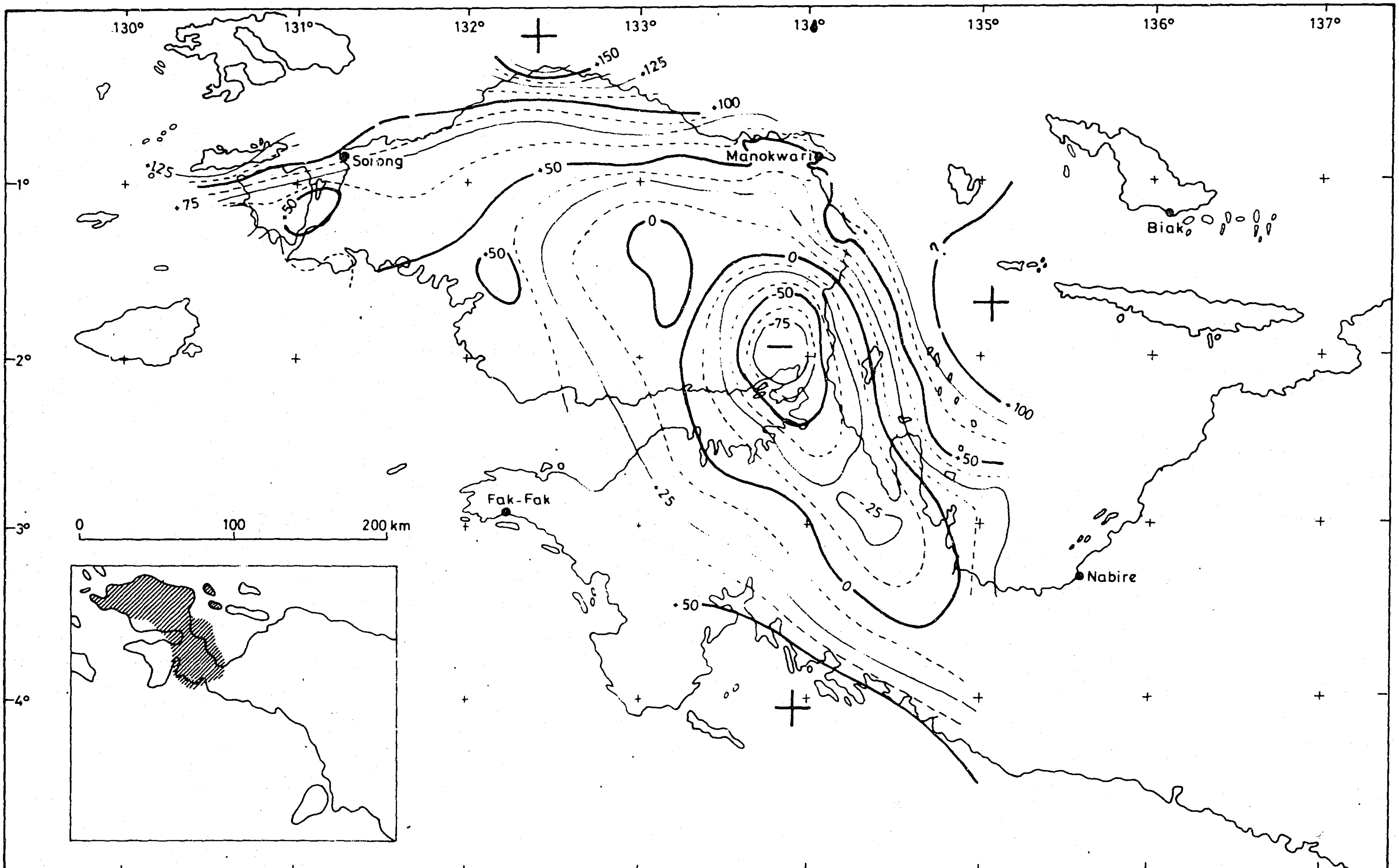

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Fig. J4 Preliminary Bouguer anomaly map, Irian Jaya geophysical survey 1978, 1979 and 1980.

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The northeastern edge of the extended low is bounded by two gravity gradients, Bouguer anomaly values rising to + 45 mGal at the northern tip of the Wandamen Peninsula and rising further, to +110 mGal, at the northern tip of Kepulauan Auri. The more westerly gradient passes northeast of Wasior, cutting across the Wandamen Fault Zone and the metamorphics exposed in Wandamen Peninsula. This gradient might be expected to include the expression of some density contrast between the sediments of the Bintuni Basin and the metamorphics, but the strike of the gradient is not parallel to the clearly defined surface faults and associated topographic expression. Bouguer anomaly values increase to +60 mGal on the northeast side of the gradient, similar to the values near Kaimana. Higher Bouguer anomaly values across the more easterly gradient suggest that the rocks under the floor of the central part of Geelvink Bay must be of very much higher density than those of the Wandamen metamorphics. Note that these high anomaly values occur 60 km south of an east-west line through Pulau Japen and Pulau Num, have the same value as Bouguer anomalies measured on Num, and are 10-20 mGal higher than values measured on Pulau Numfoor, which is 60 km north of the Japen line. These values are inconsistent with the hypothesis that the line through Japen separates continental crust to the south from oceanic crust to the north.

PUBLICATIONS AND RECORDS

PUBLICATIONS AND RECORDS

Officers of BMR report the results of their studies in a variety of BMR publications - both texts and maps - and in publications by other organisations; some results are recorded in BMR Open File Records and in Professional Opinions which, though available for inspection (and generally for copying), are not regarded as publications. Listed in this section are all available reports and papers prepared in Geological Branch during the period under review and those prepared in earlier years and issued during the period. The period of concern is from November 1979 to October 1980. The categories used are set out below; against each category the number of reports, papers, or maps issued is given. The figures in brackets are for the corresponding period last year, as listed in Record 1979/61 and microfiche Report 222.

Bulletins	: Published 8 (6) or in press 5 (9)
	: With editors 9 (8)
Reports	: Published 2 (6) or in press 5 (1)
	: With editors 8 (3)
Mineral Resources Reports	: Published 0 (1)
Contributions to BMR Yearbooks	: Published 5 (8)
	: In preparation 6 (1)
Contributions to AMI Reviews	: In press 1 (1)
BMR Journal of Australian Geology & Geophysics	: Published 24 (23) or in press 10 (2)
Other BMR publications	: With editor 3 (6)
Outside publication	: Published 2(0)
	: Published 127 (79) or in press 86 (83)
	: Submitted and accepted 15 (31), or in preparation 13 (9) (for BMR authors 'in preparation' means that the paper is with editors).

Maps. Maps are geological maps unless otherwise stated. For maps that have explanatory notes, the stage of progress indicated is that of the less advanced of the two.

1:250 000 scale Maps

Colour edition, with explanatory notes.		
	:	Published 4 (13) or in press 2(3)
	:	With editors 13 (5)
Preliminary edition	:	Published 4 (10)
(no notes)	:	Being drawn 3 (2)

1:100 000 scale Maps

Colour edition	:	Published 8 (0) or in press 1 (5)
	:	With editors 8 (4)
Geochemical maps	:	Published 0 (11) or in press 2 (0)
Preliminary edition	:	Published 13 (15) or in press 3 (2)
	:	Being drawn 6 (10)
Special Maps	:	Published 6 (2) or in press 0 (1)
	:	With editors 12 (5)
	:	Preliminary edition published 2 (2)
BMR Earth Science Atlas of Australia (Topic Sheets)	:	Published 6 (0) or in press 0 (6)
	:	With editors 2 (2)
	:	In preparation 2 (2)
Records	:	Issued 79 (34)
	:	With editors 10 (22)
	:	In preparation (being reviewed by colleagues in the Geological Branch) 8 (17)
Professional Opinions	:	Issued 22 (40)
Other unpublished works	:	5 (3)

Numbers against authors' name indicate that the author:

1 was formerly a BMR officer

2 is, or was, an officer of an Australian State Geological Survey

3 is, or was, a member of the staff of the Baas Becking Geobiological Research Laboratory, and is not, or was not, a BMR officer.

4 is, or was, a member of a university or other tertiary educational institution

5 is not, or was not, a BMR officer and does not fall into categories 1 to 4.

Year of publication or issue is not shown unless it is known to be other than 1980.

BULLETINS

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*182	[1] COOK, P.J. [1] MAYO, W.	Geochemistry of a tropical estuary (Broad Sound, Queensland)
186	SHERGOLD, J.H.	Late Cambrian trilobites from the Chatsworth Limestone, western Queensland.
189	BURGER, D.	Palynological studies in the Lower Cretaceous of the Surat Basin, Australia.
190	NICOLL, Robert S. [1] DRUCE, E.C.	Conodonts from the Fairfield Group, Canning Basin, Western Australia.
197	BLAKE, D.H. HODGSON, I.M. [2] MUHLING, P.C.	Geology of The Granites-Tanami region, Northern Territory and Western Australia.
*198	WELLS, A.T.	Evaporites in Australia.
199	EXON, N.F., WILLCOX, J.B.	The Exmouth Plateau; stratigraphy, structure, and petroleum potential.
202	[1] SMART, J. [2] GRIMES, K.G. DOUTCH, H.F. PINCHIN, J.	Geology of the Carpentaria and Karumba Basins, north Queensland.
203	VANDEN BROEK, P.H.	Engineering geology of the proposed Darwin East urban development area, Northern Territory.

204	OWEN, M. WYBORN, D.	The geology and geochemistry of the Tantangara and Brindabella 1:100 000 Sheet areas, New South Wales and Australian Capital Territory.
*205	[1] KENNEWELL, P.J. [1] HULEATT, M.B.	Geology of the Wiso Basin, Northern Territory.
*206	JACKSON, M.J. [2] VAN DE GRAAFF, W.J.E.	The geology of the Officer Basin, Western Australia.
*207	MARSHALL, J.F.	Continental shelf sediments: southern Queensland and northern New South Wales.

WITH EDITORS

175	[1] OPIK, A.A.	Dolichometopid trilobites of Queensland, Northern Territory, and New South Wales.
187	SHERGOLD, J.H.	Idamean (Late Cambrian) trilobites, Burke River Structural Belt, western Queensland.
209	PALAEONTOLOGICAL PAPERS	
	Dickins, J.M.	A Permian invertebrate fauna from the Warwick area, Queensland, and the effect of water temperature on correlation.
	Skwarko, S.K.	Mesozoic molluscs from Papua New Guinea and northern Australia (6 papers, as below).

		Some Neocomian bivalves from northern Queensland, northeastern Australia.
		A new late Mesozoic trigoniid and other bivalves from near Olsobip, western Papua New Guinea.
		First report of Megatrigoniinae/ bivalvia Cretaceous from Papua New Guinea.
		Nototrigonia cinctuta (bivalvia: mainly Early Cretaceous) in northern Queensland and Papua New guinea.
		On the Trigoniinae, Nototrigoniinae, and Austrotrigoniinae.
		Australian Cretaceous ammonites in the island of New Guinea.
	Young, G.C. [1] Gorter, J.D.	A new fish fauna of Middle Devonian age from the Taemas/Wee Jasper region of New South Wales.
	Belford, D.J.	Co-occurrence of middle Miocene larger and planktic smaller foraminifera, New Ireland, Papua New Guinea.
210	FORMAN, D.J. [1] WALES, D.W. (compilers)	Geological evolution of the Canning Basin, Western Australia.
211	KENNARD, J.M.	The Arrinthrunga Formation: Upper Cambrian epeiric carbonates in the Georgina Basin, central Australia.

212	WELLS, A.T. MOSS, F.J.	The Ngalia Basin, Northern Territory: stratigraphy and structure.
213	STAGG, H.M.J. EXON, N.F.	Geology of the Scott Plateau and Rowley Terrace, off northwestern Australia.
	Appendix by: BELFORD, D.J.	Late Cretaceous planktic foraminifera in Valdivia core KL1 from the Scott Plateau, off northwestern Australia.

REPORTS

Reports are published in microform. The MF numbers given below are the serial numbers for the microfiche.

PUBLISHED OR IN PRESS*

*214 MF92	WALTER, M.R.	Adelaidean and Early Cambrian stratigraphy of the southwestern Georgina Basin: correlation chart and explanatory notes.
216 MF104	STEWART, A.J. SHAW, R.D. OFFE, L.A. [1]LANGWORTHY, A.P. WARREN, R.G. [2]CLARKE, D.B.	Stratigraphic definitions of named units in the Arunta Block, Northern Territory.
222 MF119		Geological Branch Summary of Activities 1979.

*225 MF150	SWEET, I.P.	Definitions of new stratigraphic units in the Seigal and Hedleys Creek 1:100 000 Sheet areas, Northern Territory and Queensland.
*226 MF151	SWEET, I.P. MOCK, C.M. MITCHELL, J.E.	Chemical analyses of igneous rocks from the Seigal and Hedleys Creek 1:100 000 Sheet areas, Northern Territory and Queensland.
*227 MF147	[4]GUST, D.A. JOHNSON, R.W. [4]CHAPPELL, B.W.	Petrological data catalogue for Boisa Island, an andesitic volcano in Papua New Guinea: whole-rock, mineral, and modal analyses and modelling data.
*228	[1]WILLCOX, J.B., SYMONDS, P.A., [5]BENNETT, D., [5]HINZ, K.	Lord Howe Rise area, offshore Australia: preliminary results of a co-operative Federal Republic of Germany/Australia geophysical survey.

WITH EDITORS

181 MF153	RADKE, B.M.	Lithostratigraphy of the Ninmaroo Formation (Upper Cambrian - Lower Ordovician), Georgina Basin.
219 MF114	[1]NORVIK, M.	Permian and Late Carboniferous palynostratigraphy of the Galilee Basin, Queensland.
221 MF154	WARREN, R.G.	Geology and tectonic setting of the eastern Arunta Block.
	HABERMEHL, M.A.	Investigations of the geology and hydrology of the Great Artesian Basin, 1878-1980.
	HABERMEHL, M.A.	Springs in the Great Artesian Basin, Australia - - their origin and nature.

HABERMEHL, M.A. MORRISSEY, J.A.	Index of geophysical well logs acquired by BMR from water wells in the Great Artesian Basin, 1960-1975.
JOHNSON, R.W. [4] CHAPPELL, B.W. [5] McKEE, C.O.	Chemical analyses of late Cainozoic volcanic rocks from islands off the north coast of New Guinea and from the western end of New Britain.
WALLACE, D.A. [4] CHAPPELL, B.W. [4] ARCULUS, R.J. JOHNSON, R.W. [4] PERFIT, M.R. [4] TAYLOR, S.R. [1] TAYLOR, G.A.M.	Geological data catalogue on the Tabar, Lihir, Tanga, and Feni Islands, Papua New Guinea: field geology; major, trace-element, and isotope rock analyses; and mineral analyses.

<u>CONTRIBUTIONS TO BMR 79</u> (Published)

BAIN, J.H.C. OVERSBY, B.S. PAINE, A.G.L.	Georgetown Project, north Queensland: providing new geological guidelines for mineral exploration. 36-39.
FERGUSON, John	Star wounds: meteorite impact structures in Australia. 11-16.
JOHNSON, R.W.	Volcanological studies in Papua New Guinea (Foreign Aid). 24-29.
TINGEY, R.J.	Antarctic geoscience, and the 1979 Workshop on Antarctic Geology. 32-36.
TRUSWELL, E.M.	Australia's past climates. 39-43.

CONTRIBUTIONS TO BMR 80 (In preparation)

FORMAN, D.J. GIBSON, D. HULEATT, M.B. PERKIN, D.J. PAINE, A.G.L.	Australia's resources of energy minerals and their assessment.
JACOBSON, G.	An unusual pollution problem in Canberra.
JONES, H.	Manganese nodules on the ocean floor.
OZIMIC, S.	Storage of gas for New South Wales in natural rock reservoirs.
SIMPSON, C.	Georgina Basin Project.
STEWART, A.J.	Yilgarn geological mapping.

CONTRIBUTION TO AUSTRALIAN MINERAL INDUSTRY REVIEWS

QUARTERLY REVIEW 33(1) (In press)

JONES, H.A.	Deep sea manganese nodules in the Australian region.

BMR JOURNAL OF AUSTRALIAN GEOLOGY AND GEOPHYSICS

PUBLISHED OR IN PRESS*

Volume 4(4), 1979	BURNE, R.V. TRATT, M.H.	Epoxy relief sediment-peel and latex-replication techniques used in the study of Spencer Gulf sediments. 395-398.

	[3] JOHNS, I.A. [3] BUBELA, B.	A low-cost multichannel pH-Eh specific ion monitoring system. 398-402.
5(1)	[1,2] DRAPER, J.J.	Rusophycus (Early Ordovician ichnofossil) from the Mithaka Formation, Georgina Basin. 57-61.
	EXON, N.F. [4] MORETON, D. [4] HICKS, G.	Manganese nodules from the Tasman Sea off Sydney. 67-68.
	HABERMEHL, M.A.	The Great Artesian Basin, Australia. 9-38.
	SEIDEL, G.E.	Application of the GABHYD groundwater model of the Great Artesian Basin, Australia. 39-45.
	SENIOR, B.R. HABERMEHL, M.A.	Structure, hydrodynamics and hydrocarbon potential of the central Eromanga Basin, Queensland, Australia. 47-55.
5(2)	JONES, H.A. [2] HOLDGATE, G.R.	Shallow structure and late Cainozoic geological history of western Bass Strait and the west Tasmanian shelf. 87-94.
	[1] MUIR, M.D.	Palaeontological evidence for the Early Cambrian age of the Bukalara Sandstone, McArthur Basin, Northern Territory. 159-160.
	NICOLL, R.S.	Middle Ordovician conodonts from the Pittman Formation, Canberra, A.C.T. 150-153.

	RADKE, B.M. DUFF, P.	A potential dolostone reservoir in the Georgina Basin: the Lower Ordovician Kelly Creek Formation 160-163.
	TRATT, M.H. BURNE, R.V.	An inexpensive and efficient double-tube, hand-coring device. 156-158.
	TRUSWELL, E.M.	Permo-Carboniferous palynology of Gondwanaland: progress and problems in the decade to 1980. 95-111.
	[5]VON STACKELBERG, U. EXON, N.F. [5]VON RAD, U. [4]QUILTY, P. SHAFIK, S. [5]BEIERSDORF, H. [5]SEIBERTZ, E. [4]VEEVERS, J.J.	Geology of the Exmouth and Wallaby Plateaus off northwest Australia: sampling of seismic sequences. 113-140.
5(3)	DERRICK, G.M. [2]WILSON, I.H. SWEET, I.P.	The Quilalar and Surprise Creek Formations - new Proterozoic units from the Mount Isa Inlier; their regional sedimentology and application to regional correlations. 215-223.
	[4]KRUSE, P.D. [5]WEST, P.W.	Archaeocyatha of the Amadeus and Georgina Basins. 165-181.
	RADKE, B.M.	Epeiric carbonate sedimentation of the Ninmaroo Formation (Upper Cambrian-Lower Ordovician), Georgina Basin. 183-200.

NINTH BMR SYMPOSIUM, APRIL, 1980: ABSTRACTS

	[3] BUBELA, B.	Some aspects of interstitial water movements in simulated sedimentary systems. 257-263.
	JACOBSON, G. HILL, P.J.	Hydrogeology of a raised coral atoll - Niue Island, South Pacific Ocean.
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6562	Hedleys Creek (See 6462 - Seigal).	SWEET, I.P.

6757	Kennedy Gap	[2]WILSON, I.H. [1]HILL, R.M. [2]NOON, T.A. [1]DUFF, B.A. DERRICK, G.M.
6857	Prospector	[2]WILSON, I.H. DERRICK, G.M. [1]HILL, R.M. [1]DUFF, B.A. [2]NOON, T.A. [1]ELLIS, D.J.
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8626	Tantangara (Bulletin 204 precludes the need for a Commentary)	OWEN, M. WYBORN, D.
8627	Brindabella (Bulletin 204 precludes the need for a Commentary)	OWEN, M. WYBORN, D.

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5473	East Alligator	NEEDHAM, R.S.

5573, part 55572	Geology of the Nabarlek Region (Special).	NEEDHAM, R.S.
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8826	Araluen	WYBORN, D. OWEN, M.

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SPECIAL MAPS

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1:1 000 000	Continental shelf sediments: Tasmania-Bass Strait.	DAVIES, P.J. JONES, H.A. MATVEEV, G.
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1:1 000 000	Geophysics of the Officer Basin, Western Australia.	JACKSON, M.J.
1:50 000	Geology of Canberra, Queanbeyan & environs (with notes).	HENDERSON, G.A.M.
1:10 000	A.C.T. engineering geology: Central Canberra (with notes).	HENDERSON, G.A.M.
1:10 000	A.C.T. engineering geology: Woden-Weston Creek.	HENDERSON, G.A.M.
1:500 000	Southern Prince Charles Mountains (Antarctica).	TINGEY, R.J.
1:500 000	Geology of the Ngalia Basin.	WELLS, A.T.

1:500 000	Solid geology and geophysics - Ngalia Basin.	WELLS, A.T.
1:10 000 000	Geology of Australia. (Compilation only, for geological map of the southwest quadrant, being produced by USGS for the CIRCUM-PACIFIC MAP PROJECT).	D'ADDARIO, G.W. PALFREYMAN, W.D. [1] JONGSMA, D. MIKOLAJCZAK, A.J.
1:5 000 000	Geology of Australia. (Compilation only, for 3rd series, Atlas of Australian Resources, being produced by Division of National Mapping).	D'ADDARIO, G.W. PALFREYMAN, W.D. STEWART, A.J. [1] BULTITUDE, J.M. CHAN, R.
1:5 000 000	Metamorphic map of Australia (Compilation only, under direction of Prof. T.G. Vallance, University of Sydney, for Commission for the Geological Map of the World).	MITCHELL, J.E. D'ADDARIO, G.W. STEWART, A.J. MIKOLAJCZAK, A.J.

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1:10 000 000	Geology (1979).	D'ADDARIO, G.W. PALFREYMAN, W.D. [1] BULTITUDE, J.M.
	Commentary (1980) by	DERRICK, G.M.
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1975/100 MF107	SHAW, R.D. WARREN, R.G. SENIOR, B.R. YEATES, A.N.	Geology of the Alcoota 1:250 000 Sheet area.
1977/34	GARDINER, J.E.	Heavy-mineral deposits along the coast of Western Australia.
1978/11	CRICK, I.H.	Interim report on the Batchelor 1:100 000 Sheet (5171), N.T.
+1978/16	[1]PURCELL, D.C. [5]TRAND, G.	Melbourne cable tunnels geological investigations, 1977-78.
+1978/24	HENDERSON, G.A.M.	Geological notes on proposed Sullivans Creek to Commonwealth Avenue pumping station sewer augmentation and possible extension to King Edward Terrace, Canberra, A.C.T.

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+1978/64	WILSON, E.G.	The contamination of groundwater by hydrocarbons, with brief notes on the hydrogeology of Canberra City, A.C.T.
+1978/81	[1] HOHNEN, P.D. KELLETT, J.R. JACOBSON, G.	Evaluation of proposed site for disposal of radio-active waste, West Belconnen, 1978.
1978/87	MOCK, C.M.	Geology of the Oban 1:100 000 Sheet area, northwestern Queensland: progress report.
+1978/96	[4] HARVEY, N. DAVIES, P.J. MARSHALL, J.F.	Shallow reef structure: southern Great Barrier Reef.
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+1979/22	PASSMORE, V.L.	Carpentaria and Karumba Basins explanatory notes and stratigraphic columns.
1979/24	[2]WILSON, I.H. [1]HILL, R.M. [2]NOON, T.A. [1]DUFF, B.A. DERRICK, G.M.	Geology of the Kennedy Gap 1:100 000 Sheet area (6757), Queensland.
1979/27	[1]PURCELL, D.C.	Molonglo Valley Interceptor Sewer, A.C.T., engineering geology completion report, 1978.
+1979/31	FITZSIMMONS, J.L.	Miscellaneous chemical, petrographic and mineragraphic investigations carried out in the geochemical laboratory, January-December 1978.
1979/32	[1]GORTER, J.D. [1]RASIDI, J.S. [1]TUCKER, D.H. BURNE, R.V. PASSMORE, V.L. [1]WALES, D.W. FORMAN, D.S.	Petroleum geology of the Canning Basin.

1979/36	SHERGOLD, J.H. WALTER, M.R.	BMR stratigraphic drilling in the Georgina Basin, 1977 and 1978.
1979/37	[1]ROSSITER, A.G. SCOTT, P.A.	Stream-sediment geochemical data Seigal 1:100 000 Sheet area, Northern Territory.
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1979/45	SWEET, I.P. [2]HUTTON, L.J.	Gregory Downs and Riversleigh - 1:100 000 Sheet areas: catalogue of geological compilation sheets.
1979/47 MF133	SHAW, R.D. [1]LANGWORTHY, A.P. OFFE, L.A. STEWART, A.J. [4]ALLEN, A.R. SENIOR, B.R.	Geological report on 1:100 000-scale mapping of the southeastern Arunta Block, Northern Territory.
with contributions by	[4]WOODFORD, P.J. [4]IYER, S.S. [4]WILSON, A.F. [2]CLARKE, D.B.	
1979/51	BROWN, C.M.	Bonaparte Gulf Basin explanatory notes and stratigraphic correlations.

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1979/61		Geological Branch Summary of Activities, 1979.
1979/62	EXON, N.F.	Deep-sea sediments and manganese nodules from the southern Tasman Sea.
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1979/67	SCOTT, P.A. [1]ROSSITER, A.G.	Stream-sediment geochemical data - Georgetown 1:100 000 Sheet area, north Queensland.

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1979/69	SHERATON, J.W.	Inventory of Antarctica rock specimens held in Australian Institutions.
1979/70	SHERGOLD, J.H.	Georgina Research, September Quarter 1979.
1979/72	BROWN, C.M.	Murray Basin Hydrogeological Project: Progress report, September Quarter 1979.
1979/77	EVANS, W.R. JACOBSON, G. BENNETT, D.G.	Geological and geophysical investigation of the Pialligo Landfill site, A.C.T.
1979/82	PLUMB, K.A. (Co-ordinator)	McArthur Basin research, September Quarter 1979.
1979/83	[1] GOLDSMITH, R.C.M.	Geological report on construction of the Googong Dam, Queanbeyan River, NSW, 1975-1977.
1979/84	WILSON, E.G.	Observations on geology, soils and groundwater relevant to pavement failure in Canberra 1979.
1979/85	DERRICK, G.M.	Geochemical data, Marraba 1:100 000 Sheet area, northwest Queensland.

1979/86	BLAKE, D.H. JAQUES, A.L. [2]DONCHAK, P.J.T.	Precambrian geology of the Selwyn region, northwestern Queensland - preliminary data.
1979/88	KELLETT, J.R. EVANS, W.R. JONES, B. GUY, D.B.	Progress report on hydrogeological studies in the Magela and Cooper Creek catchments, Alligator Rivers region, NT, 1979.
1979/89 MF126	[1]JOHNSON, K. HONE, I.G. [1]INGRAM, J.A. CRICK, I.H.	Stratigraphic drilling in the Rum Jungle area, NT, 1973-74: geological results.
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1980/2	[2]WITHNALL, I.W. OVERSBY, B.S. BAIN, J.H.C. [2]BAKER, E.M.	Geology of the Gilberton 1:100 000 Sheet area (7659), north Queensland - data record.
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1980/7	STRUSZ, D.L.	Supplement to "The Encrinuridae and related trilobite families, with a description of Silurian species from Southeastern Australia.

1980/9	HABERMEHL, M.A.	Wire-line logging of water-wells in the Great Artesian Basin - ADP data transcription manual.
1980/11	[1]HOHNEN, P.D.	Geology and groundwater hydrology of Freshford, west Murrumbidgee urban development area, A.C.T.
1980/13	PERRY, W.J.	Murray Basin Hydrogeological Project: Progress report, December Quarter 1979.
1980/14	JACOBSON, G. HILL, P.J.	Groundwater resources of Niue Island.
1980/15	STUART-SMITH, P.G. WALLACE, D.A. ROARTY, M.J.	Pine Creek Party 1978 data record: Point Stuart, Mary River and Mundogie 1:100 000 Sheet areas, NT.
1980/16	BULTITUDE, R.J.	Precambrian geology of the Ardmore 1:100 000 Sheet area, northwestern Queensland - preliminary data.
1980/17		Abstracts 9th BMR Symposium, Canberra, 29-30 April 1980. For contributions by Geological Branch Officers see under BMR JOURNAL OF AUSTRALIAN GEOLOGY AND GEOPHYSICS Vol 5(3).

1980/19	WALLACE, D.A.	Shallow stratigraphic drilling in the Munmarlary area, Alligator Rivers region, NT, 1978.
1980/20	[1] KENNEWELL, P.J.	Lithological logs of stratigraphic holes and water-bores drilled to 1976 in the Wiso Basin, Northern Territory.
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1980/23	WYBORN, D.	GANOVEX 1979-80. Brief comments on the planning, implementation, and results of the German North Victoria Land Expedition to Antarctica.
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1980/43	SWEET, I.P. 2 HUTTON, L.J.	Geology of Lawn Hill-Riversleigh region.
1980/50	CHAPRONIERE, G.C.	Supplement to "Biometrical studies of early Neogene larger Foraminifera from Australia and New Zealand".
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1980/54	DOW, D.B.	Palaeozoic rocks of the Hardman, Rosewood and Argyle Basins, East Kimberley region, Western Australia.
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1980/59	EVANS, W.R.	Geological evaluation of the proposed Dalton to Canberra natural gas pipeline.

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1980/24	[1]HUTCHISON, D.S. [1]NORVICK, M.	Geology of the north Sepik region, Papua New Guinea.
1980/30	TOWNER, R.R. GIBSON, D.L.	The geology of the onshore West Canning Basin, Western Australia.
1980/33	STUART-SMITH, P.G. NEEDHAM, R.S. ROARTY, M.J. CRICK, I.H.	Geology of the Mundogie 1:100 000 Sheet area, Northern Territory.

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1980/44	WARREN, R.G.	Summary of mineral deposits in the Alice Springs 1:250 000 Sheet area, by commodities.
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GLIKSON, A.Y. [2]HICKMAN, A.H.	Geochemistry of Archaean volcanic successions, eastern Pilbara Block, Western Australia.
KELLETT, J.R.	Hydrogeological investigations in two basins at Lanyon, A.C.T., 1974-1976.
[1]PURCELL, D.C. [1]VANDEN BROEK, P.H.	Ginninderra sewer tunnel, A.C.T.: engineering geology completion report, 1979.
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PROFESSIONAL OPINIONS (Issued)

Geol. 79.031	RADKE, B.M.	Former sulphates in carbonates, Sorby Hills Prospect, Bonaparte Gulf Basin.
Geol. 79.032	MACKENZIE, D.E.	Petrographic examination of pottery and stone axe heads from archaeological sites in the Kikori area, Gulf of Papua.
Geol. 79.033	CARTER, E.K.	Nabarlek Uranium Project, N.T.: Comments on proposal to dispose of mill tailings in mine pit.
Geol. 79.034	NICOLL, ROBERT S.	A late Devonian age for the Munabia Sandstone,Carnarvon Basin, W.A.
Geol. 80.001	[1] MUIR, M.D.	Petrological report on cherty material from the 1100 orebody, Mt. Isa mine.
Geol. 80.002	CHAPRONIERE, G.C.H.	Microfossils in samples from Kaimana, Ransiki, Steenkool and Taminabual areas, Irian Jaya.
Geol. 80.003	CHAPRONIERE, G.C.H.	Foraminiferal faunas in samples from the Wabag 1:250 000 Sheet area, Papua New Guinea.
Geol. 80.004	NEEDHAM, R.S. PAGE, R.W. STUART-SMITH, P.G.	Report on a reconnaissance of the Litchfield Block, N.T.: 1-3 August, 1979.

Geol. 80.005	CARTER, E.K.	Koongarra Uranium Project, N.T.: Comments on draft and final environmental impact statements.
Geol. 80.006	NICOLL, ROBERT S.	Conodont identifications - Esso Puratte No. 1 well, Canning Basin, W.A.
Geol. 80.007	TRUSWELL, E.M.	Reconnaissance palynology of samples from BMR stratigraphic boreholes in the Canberra 1:100 000 Sheet area.
Geol. 80.008	JACOBSON, G.	Recommended groundwater investigation for Tarawa, Kiribati.
Geol. 80.009	TRAIL, D.S.	Reconnaissance visit to coal mines in the Bowen Basin, Queensland, October 1979.
Geol. 80.010	EVANS, R.	Bore site for Section 102, Majura, A.C.T.
Geol. 80.011	BURGER, D.	Palynological examination of samples from FPC Galway 1, Windorah 1:250 000 Sheet area, Queensland.
Geol. 80.012	EVANS, R.	Potential for groundwater use, Canberra racecourse.
Geol. 80.013	KELLETT, J.R.	Step drawdown test on water bore PR5, Birrigai Youth Camp, Tidbinbilla, A.C.T.

Geol. 80.014	WELLS, A.T.	Notes on visit to eastern Officer Basin, South Australia.
Geol. 80.016	BURGER, D.	Preliminary palynological notes on BMR Urisino 1, N.S.W.
Geol. 80.017	BURGER, D.	Palynological examination of late Palaeozoic and Jurassic samples from the Olive River area, Cape York Peninsula.
Geol. 80.018	JACOBSON, G.	Inspection of gravel deposit, Flowerdale, Tasmania.
Geol. 80.019	TRUSWELL, E.M.	Palynological examination of samples from near Hobartville Homestead, Jericho 1:250 000 Sheet, Galilee Basin, Queensland.

OTHER UNPUBLISHED WORKS

JACKSON, M.J.	Zambian and Kupferschiefer copper deposits.	M.Sc. Seminar, James Cook University, north Queensland.
JACKSON, M.J.	The sedimentology of three formations from the McArthur Basin.	M.Sc. Seminar, James Cook University, north Queensland.
JACKSON, M.J.	The role of the BMR in the geological exploration of the McArthur Basin, N.T., Australia.	M.Sc. Seminar, James Cook University, north Queensland.

JAQUES, A.L.	Petrologic and experimental studies on the petrogenesis of Papua New Guinea ophiolites.	Ph.D. thesis, University of Tasmania.
MACKENZIE, D.E.	Volcanoes of the Papua New Guinea highlands: volcanism on a continental margin and its relationship to subduction.	Ph.D. thesis, University of Melbourne, 1980.