1978/89

DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1978/89

GEOLOGICAL BRANCH

SUMMARY OF ACTIVITIES

1978

Chief Geologist: J.N. Casey

Note: The original Record contains transparent overlays for Frontispiece 1 and 2. If you wish to view the original, please contact the N.H. (Doc) Fisher Geoscience Library.

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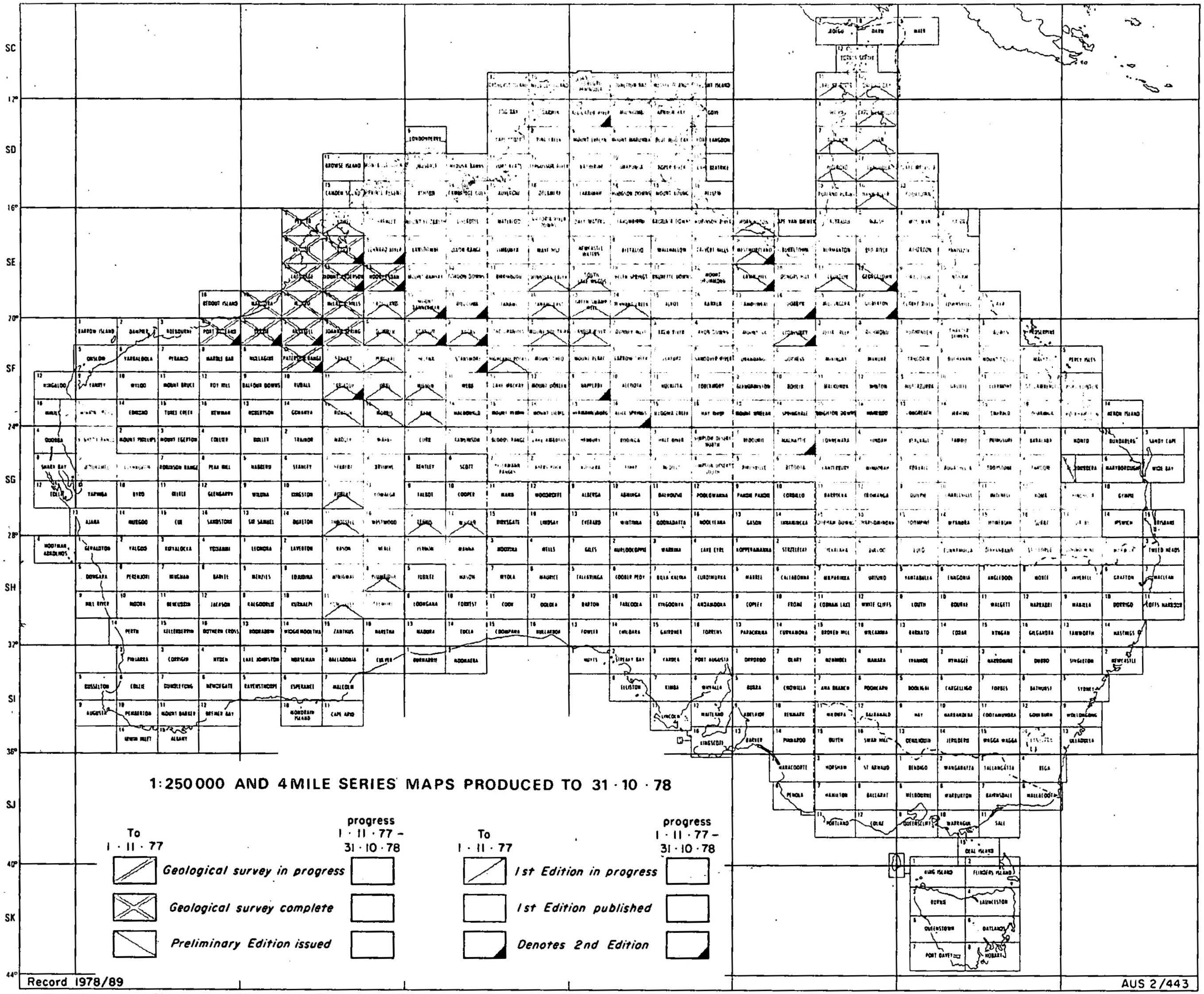


ANTARCTICA

1:250000 SERIES MAPS

PRELIMINARY EDITION ISSUED - TO 1 · 11 · 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 · 78

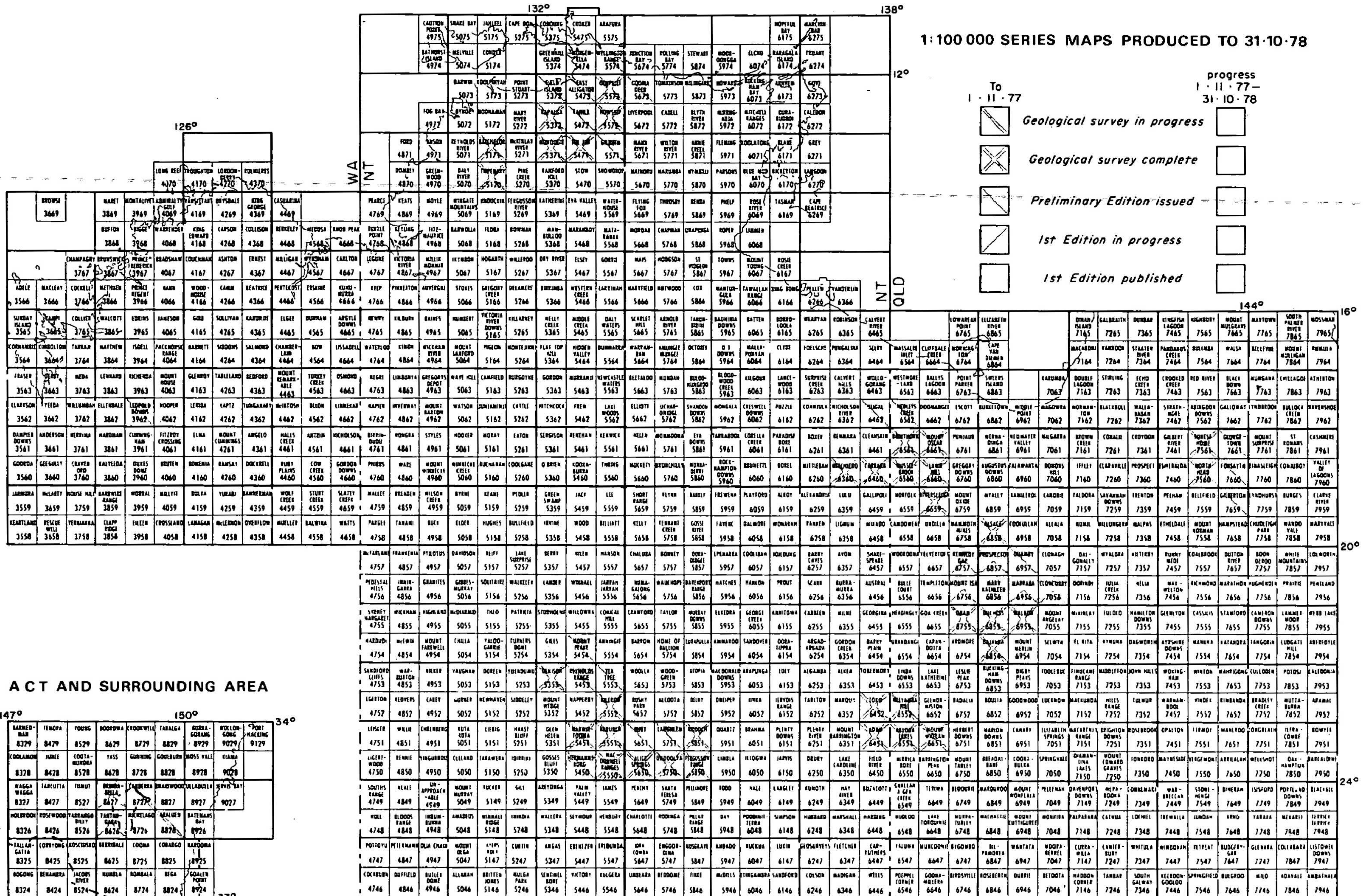
ENDERBY LAND FIELD STUDIES

Geological mapping - Summer 76/77

Geochronological and structural studies - Summer 77/78

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)



Record 1978/89

AUS 2/444

SEE UNDERSHEET

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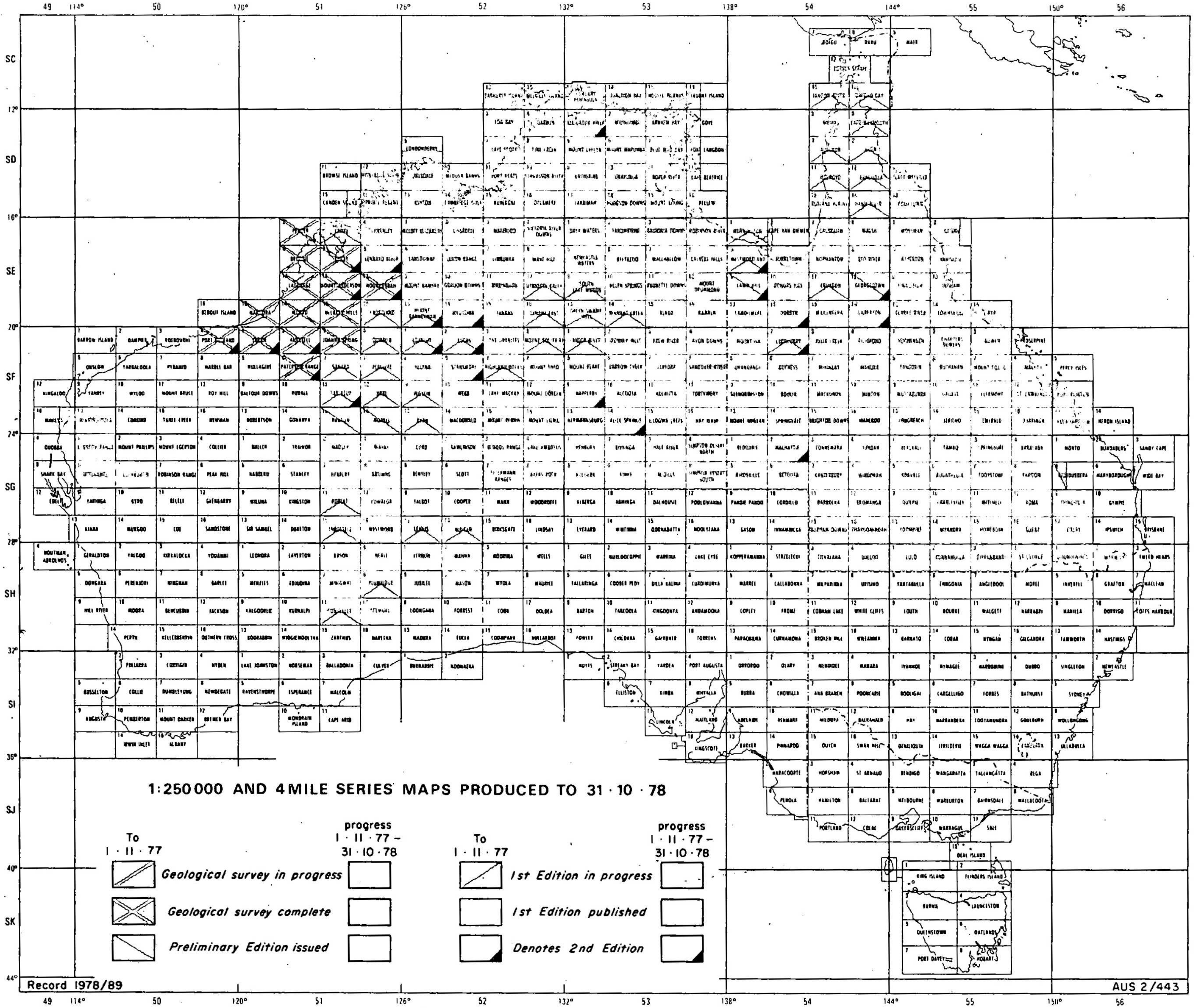

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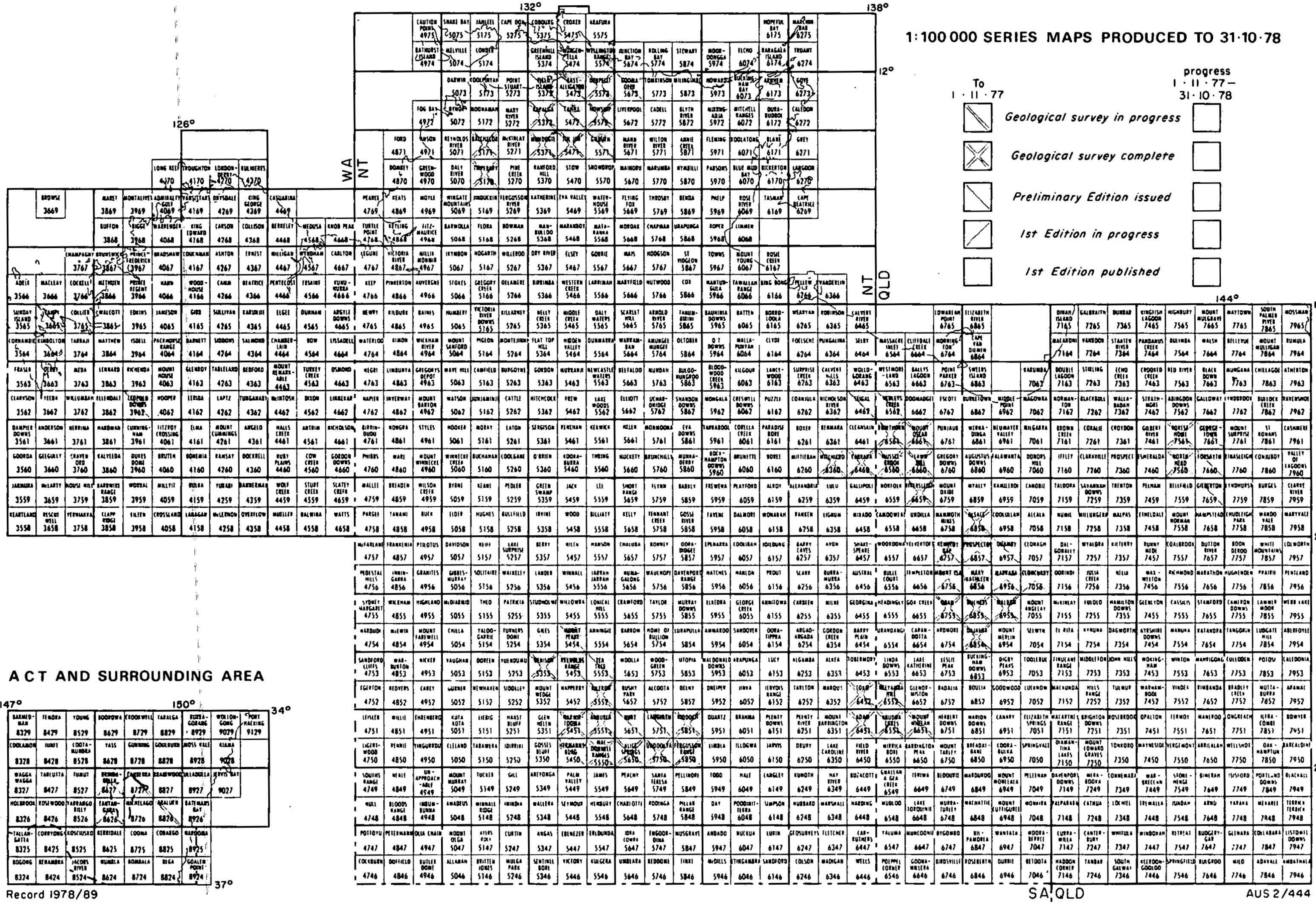

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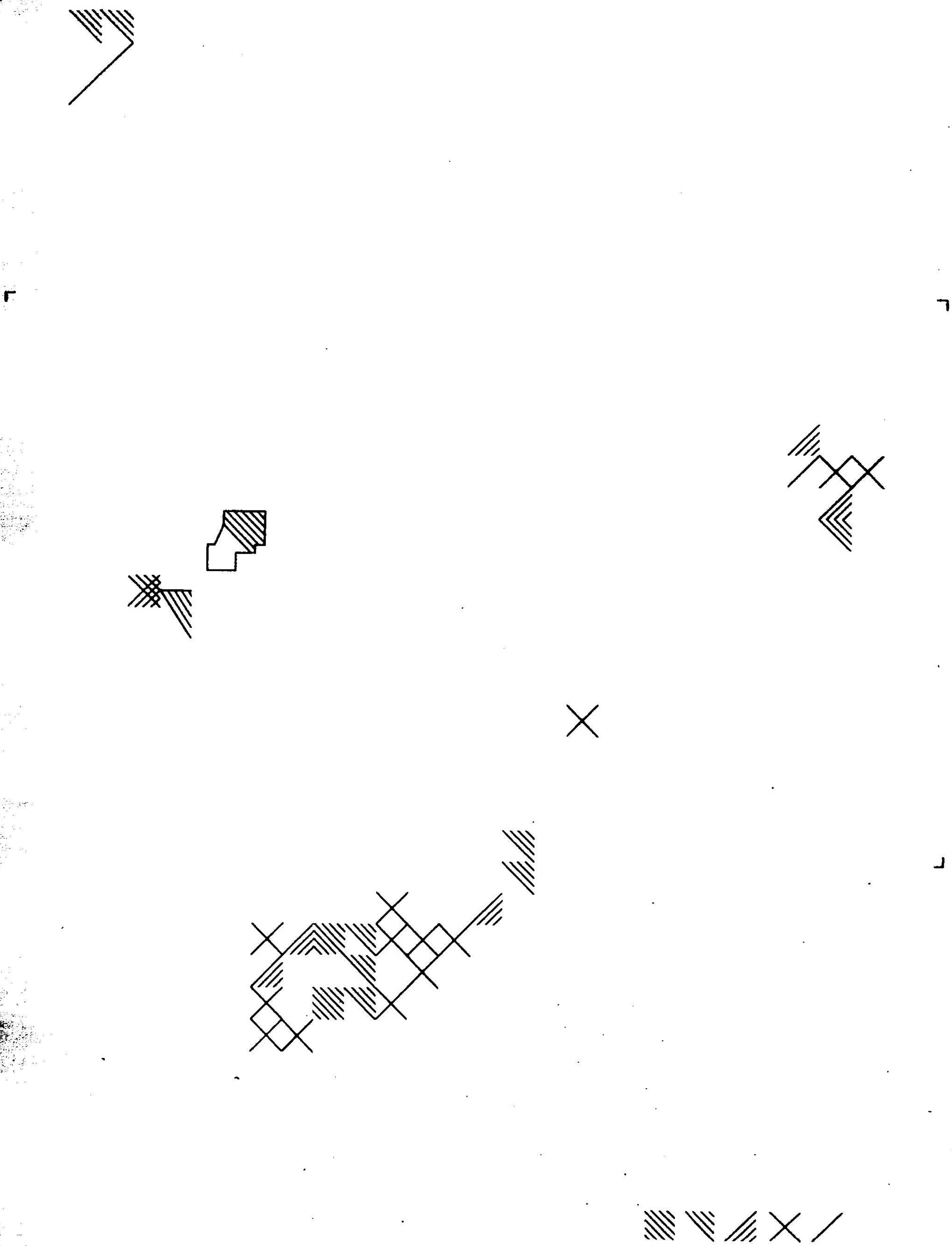

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Frontispieces

State of geological mapping and series map production at 31st October 1977 and (on overlay) progress in geological mapping and series map production in the year ended 31st October 1978.

(1) 1:250 000 (and 1 inch : 4 miles) scale maps
(2) 1:100 000 scale maps

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TABLES

GENERAL SUMMARY

SEDIMENTARY SECTION

by

G.E. Wilford

Work on the synthesis of information on sedimentary basins continued throughout the year, following the completion of field research in those areas in previous years. Bulletin texts together with comprehensive geological maps at 1:1 000 000 or 1:500 000 scale on the Wiso (N.T.), Officer (W.A.) and Ngalia Basins should be completed early in 1979. The production of 1:250 000 scale geological maps and accompanying explanatory notes covering the Canning Basin continued. By the end of the period maps and notes for 19 of the 31 sheet areas that cover the basin had been published or were in press, and compilation of the remaining ones was in progress. A review of source rock data from the Canning Basin, made in co-operation with CSIRO, indicates that only a few parts of the basin appear to have favourably juxtaposed source and reservoir rock lithologies. There has been relatively little concerted interest in petroleum exploration in the Eromanga Basin sequence. Many wells that penetrate the sequence have been drilled to targets below the basin, or have explored only the broader fold structures. A study was therefore started to analyse groundwater flow data from the Great Artesian Basin study, to identify structures from LANDSAT and regional geophysical data, particularly faults normal to flow patterns, with the object of identifying likely reservoirs protected from flushing. Source rock analyses are also being carried out in co-operation with CSIRO.

Work essential for the revision of the geology of the Canberra 1:250 000 Sheet area, in co-operation with the Engineering Geology Group and the Geological Survey of New South Wales, continued. The Bulletin on the Tantangara and Brindabella 1:100 000 scale sheets was submitted for editing, fieldwork on the Canberra 1:100 000 sheet was completed and about 75% of the Araluen 1:100 000 sheet was mapped. Unexpected was the presence of easterly trending basic dyke swarms in the Araluen Sheet area. They cut granites, and are as much as 10 km long and are thought to be of Devonian age.

As in previous years the photogeology and remote sensing group assisted with the interpretation of colour air photographs for major field projects, both in the office and during field visits. Research into the applications of Landsat imagery in co-operation with CSIRO continued.

Refinements to draft reporting on the mathematical computer-based model of the Great Artesian Basin (GABHYD) continued throughout the year. Its operation and its value as a predictive tool were explained to State water authorities and others at a workshop held in August. Studies of the isotopes in the groundwater of the Great Artesian Basin are being made in collaboration with the Australian Atomic Energy Commission, the object being to determine flow rates and directions, and the origin of the water. Results to date indicate flow rates in the eastern part of the basin of 1 to 5 m per year. Variations in chloride levels are thought to correlate with rates of infiltration of re-cycled salt, itself a function of climatic change during glacial and interglacial periods.

A submersible rotary drill was designed, built and successfully used to core material in the southern Great Barrier reef, particularly the pre-Holocene substrate of the present reefs. Studies of surface morphology and shallow seismic profiling were also undertaken in co-operation with the Geological Survey of Queensland. Evidence to data emphasises the overwhelming influence of pre-Holocene karst erosion features on present reef morphology.

Reporting continued on the earlier reconnaissance investigations of the continental shelf of southeastern Australia. A map showing sediment type distributions along the shelf bordering southern Queensland and northern New South Wales was printed. A comprehensive bulletin containing descriptions of the morphology, structure, composition and geochemistry of the superficial sediments is with the editors. Mineralogical and geochemical work was carried out on the surface sediments of the Bass Strait and east Tasmania continental shelves.

Following participation in cruises on board the Federal Republic of Germany's R/V Valdivia in 1977, laboratory and interpretative work was undertaken. Sampling in the vicinity of the Scott Plateau and the Timor Trench, off the northwest shelf, revealed that break-up there was preceded by basin volcanism and shallow marine sedimentation, that restricted marine conditions followed in the Late Jurassic, and that bathyal carbonate sedimentation prevailed by the Late Cretaceous. Sedimentological studies of pelagic and turbidite sedimentation in the 5000 m deep Sulu Sea were undertaken at Kiel University under the auspices of the Australia-Federal Republic of Germany Science Agreement.

Substantial progress was made by the Palaeontological Group in describing, curating and expanding the national fossil collection. New collections were made from type and critical sections in the Bonaparte, Canning and Carnarvon Basins and several palaeontologists worked full or part-time as members of a team studying the Georgina and McArthur Basins, and the Lachlan Fold Belt in the Canberra area. New sites yielding Tertiary mammals were found in northeast South Australia. In addition to the many papers published or submitted for outside journals major works with the printers or editors include bulletins on Lower Cretaceous pollen, Tertiary ground-birds, Cambrian agnostid trilobites and Chatsworth area (Georgina Basin) trilobites. Major advances were made in the understanding of palaeoclimates, particularly for the Permian and Cainozoic and in increasing the number of known Precambrian microfossil assemblages.

Several staff are involved in International Geological correlation projects. Activities in 1978 included organising, with others, an international field workshop and seminar for Project 156 (Phosphorites:Proterozoic/Canbrian of Australia & Asia), and the contribution to an atlas of stratigraphic columns of the ESCAP region (Project 32). One person was seconded to ESCAP in Bangkok as stratigrapher to co-ordinate the latter project throughout the ESCAP region.

GEOLOGICAL SERVICES SECTION

by

E.K. Carter

The Engineering Geology Sub-section continued to provide engineering geology and hydrogeology services for Canberra and its environs. With the completion of Googong Dam, the 4.2 km long Ginninderra Sewer Tunnel was the main project for which construction services were provided. Excavation for the tunnel was completed in late September. Investigation services were provided for a proposed new 2 km long, 2 m diameter relief sewer from Gould Street, Turner, to the north end of Commonwealth Avenue Bridge. Lesser services were provided for other major engineering works under investigation or construction in the A.C.T.

A.C.T. hydrogeological investigations and services included bore siting and groundwater supply advice for several landholdings, golf courses, the Australian National University campus, and the site for the National Fitness Camp at Tidbinbilla. Two bores were successfully sited, and proved by pump testing on construction, in hydrogeologically difficult granite terrain at the National Fitness Camp. In nearby N.S.W. the monitoring of Lake George and analysis of results continued, and installation of instrumentation for a long-term study, jointly with CSIRO, of the upper Yass River representative basin, made substantial progress.

Further work on the body of groundwater polluted by hydrocarbons in the city area led to an abatement of the problem. Studies were made of several other pollution problems, or potential problems, including the feasibility of disposing of low-level radioactive wastes at the West Belconnen landfill site. Remedial measures implemented as a result of a study of waterlogging of the Seiffert Oval, Queanbeyan, proved successful.

Further soil stratigraphic studies over the three major types of rock encountered in the A.C.T. - volcanics, sedimentary rocks and granite - are producing a useful body of information and interpretation; for example the age relationships of soils and weathering surfaces and the climates that have produced the soils investigated are being established.

Compilation of a new geological map of Canberra-Queanbeyan, at scale 1:50 000, was completed, with notes, and is now being fair-drawn. Work continued on several 1:10 000 scale engineering geology maps of urban Canberra, with notes; one map - Coppins Crossing - is being fairdrawn.

Beyond the A.C.T. and its environs, the Engineering Geology Subsection's work covered three main areas: supervision and interpretation of geological investigations for proposed cable tunnels at shallow depth beneath several city streets in Melbourne, for Telecom. Design investigations are now complete design and assessment of investigations for foreign aid projects in Fiji (Suva sewer tunnel) and South Sumatra (water supplies) review of draft environmental impact statements and management programs for six mining and milling projects in the Northern Territory and Western Australia.

The editing of maps, and advice to field geologists on map preparation, was maintained throughout the year; twenty-three maps were edited. The

Map Editing and Compilation Group, which compiles small-scale regional and national maps, continued work on several compilation projects. Preparation of 1:1 000 000 scale maps for the BMR Earth Science Atlas was the main activity; work was done on seven maps and/or their accompanying notes. Four of the maps are almost completely fairdrawn and two have been compiled. Other projects on which work was done are: 1:5 000 000 scale compilation of the geology of Australia for the 3rd series of the Atlas of Australian Resources; 1:10 000 000 scale sedimentary sequences of Australia map for the ESCAP Stratigraphic Atlas; 1:10 000 000 scale geology of Australia and offshore areas for the Circum-Pacific Map Project; and the 1:5 000 000 scale C.G.M.W. metamorphic map of Australia. Some progress was made with notes for various maps.

The Central Registry of Stratigraphic Names was maintained throughout the year: current literature was indexed (229 new names, 46 definitions), 6 bimonthly variations lists were issued, the annual deletions list was issued, 47 definition cards were filed and enquiries were answered.

During the year work was resumed on the preparation of mineral reports: a start was made on the study of fluorite.

The Museum staff maintained their collecting, curatorial, research, education and information services. Two discoveries of rare minerals - pseudomalachite from near Tottenham, N.S.W. and kornerupine in the Harts Range, central Australia - were made. A number of attractive and valuable display minerals were added to the collections by donation, exchange and purchase. Cataloguing and computer coding of the Doo Collection, the last named collection to be so recorded, continued. A wide range of services were provided to the public, Government bodies, educational institutions, research bodies and public organisations, and to other BMR staff; the services ranged from simple identification of minerals to substantial matters of scientific advice. School collection sets were built up, and nine sets supplied. Displays were provided for four exhibitions or localities out of Canberra and local displays were maintained. More than 1000 visitors, including 405 children in school parties, visited the Museum and assistance was given on several school excursions.

A total of 5430 samples and specimens were despatched by the Transit Officer for preparation of thin sections, chemical analyses, age determination, or XRD identification.

METALLIFEROUS SECTION

by

W.B. Dallwitz

The progress of field research and preparation and publication of geological maps is shown in Frontispieces 1 and 2. Work was carried out on about 28 projects of various magnitudes during the year. Final reports were written on some of these, and over 150 progress reports, internal publications, maps, and outside publications were prepared, or are in preparation.

Depending on job requirements, and within limits imposed by staff numbers, field and laboratory investigations were carried out as multidisciplinary projects wherever possible.

The major field efforts this year were in the Mount Isa-Lawn Hill and Duchess areas and in the Pine Creek Geosyncline. Traversing by helicopter contributed greatly to the completion of 1:100 000 mapping in the Duchess-Westmoreland region; about two months' field work is planned for next year to help resolve differences in interpretation and correlation that have arisen in areas mapped by different parties.

Fieldwork in the Arunta Block was restricted to re-examining problem areas for preparation of the second-edition Alice Springs 1:250 000 map, and obtaining information on the original nature and stratigraphic position of host formations to Oonagalabi-type Zn-Pb-Cu lodes. Further advances were made in the correlation of lithological units in the Alice Springs 1:250 000 Sheet area, and in the understanding of the metamorphic history of that area.

Correlations previously established in the eastern part of the Pine Creek Geosyncline were carried through to the Rum Jungle area, and carbonate pseudomorphs after evaporite minerals were found in the Celia Dolomite and the Cahill Formation. An interpretative solid-geology map of the Geosyncline was compiled at 1:500 000 scale.

Collecting for isotopic dating was carried out in Enderby Land during the 1977-78 field season; results are awaited with particular interest because of a 4000-m.y. age reported by the Russians, but whatever the outcome they should lead to a better understanding of the geological history of the area.

In the Mount Oxide-Mammoth Mines region, Mount Isa and Lawn Hill geological investigations were linked. The nature of a major Proterozoic rift structure - the Leichhardt River Fault Trough - was further documented. Eastern Creek Volcanics extend farther west than previously thought, and red-bed and stromatolitic sequences are widespread. A recently recognised basalt-rhyolite suite, the Fiery Creek Volcanics, underlies the mainly dolomitic McNamara Group, in which extensive intertidal and locally evaporative environments were recognised, together with zones prospective for Lady Loretta-type Ag-Pb-Zn mineralisation. A major palaeogeographic rise, the Mount Gordon Arch, modified sedimentation within the rift structure, and partly controlled mineralisation along the Mount Gordon Fault Zone.

In the eastern half of the Duchess 1:250 000 Sheet area the 1978 field work showed that rocks previously mapped as Kuridala and Soldiers Cap Formations are almost certainly stratigraphic equivalents. Their relationship to the adjacent Corella Formation is equivocal. Halite casts associated with porphyroblastic scapolite were found in some rocks mapped as Corella Formation. To the west, in the Ardmore 1:100 000 Sheet area, the Precambrian rocks are represented mainly by basic volcanics ranging from the lower-greenschist to about middle-amphibolite grade of regional metamorphism.

Fieldwork in the Georgetown Project was confined to check mapping, stratigraphic drilling, and section measuring. The results of the last five years' field research were outlined and discussed in three review papers prepared for and delivered at the Third Australian Geological Convention in Townsville in August. As an additional aspect of communicating the results of the project work, some thirty company and government survey geologists were taken on a conducted six-day safari tour of the Georgetown region; the excursion guide book was published by the Geological Society of Australia.

For the study of the Quaternary volcanic rocks of PNG, 1978 was a year largely devoted to the interpretation of a wide range of data, and to integrating the results into models for the late Cainozoic evolution of the region. New microprobe data were obtained on minerals, and rare-earth-element determinations and Sr and Nd isotopic analyses were made by workers at ANU and the California Institute of Technology; these data, combined with other information, are being used to prepare a wide range of collaborative reports.

Important petrological results have been obtained from a study of kimberlite from Jugiong, N.S.W. These are of interest for the recently-initiated Crust and Upper Mantle Project covering southeastern Australia.

Basaltic rock fragments containing nodules of spinel lherzolite, spinel pyroxenite, and serpentine were dredged from an area near the junction of the Diamantina and Naturaliste Fracture Zones which were formerly parts of a continental rift system.

Further laboratory studies of sapphirine-quartz and osumilite-bearing granulites from Enderby Land, Antarctica, suggest that regional metamorphism there took place at temperatures of at least 900°C and pressures of 8-9 kb.

Samples of granitoid rocks from the Mount Isa Inlier have been collected for a comprehensive study of their geochemistry, intrusive history, and economic potential, for determining their relation to felsic volcanic suites, and for seeing what light they throw on regional crustal evolution.

A large volume of data obtained for the Pilbara Geochemical Project is being treated by a comprehensive range of computer programs.

Six geologists, including four from North America and one from ANU, spent several weeks studying the Strangways crypto-explosion structure, southeast of Mataranka, N.T.; a large quantity of material was collected for laboratory study.

A comprehensive petrological, geochemical, geophysical, and mineralogical study of a wide spectrum of rocks, and of uranium mineralisation, in the Pine Creek Geosyncline is at the writing-up stage. Many of the results will be presented at the International Uranium Symposium in Sydney in June, 1979.

Preliminary results from a soil and stream-sediment geochemical survey under way in the Araluen 1:100 000 Sheet area have disclosed several areas with anomalous lead-zinc values and two areas anomalous in arsenic (possibly attributable to the common association of As with Au).

A stream-sediment geochemical survey was carried out in the Mammoth Mines 1:100 000 Sheet area, northwest Queensland. Computer processing of results from previous surveys continued, and drafting of maps has been almost completely automated.

Case histories have been prepared for a forthcoming volume on geochemical exploration in Australia.

A study of skarn development and associated uranium mineralisation in the Mary Kathleen area points to addition of Ti, Al, Mn, and U, and removal of Mg, Ca, and K in the metasomatised rocks.

The Analytical Laboratory produced about 80 000 element determinations in support of various field projects; if carried out by a commercial laboratory this work would have cost about $200 000.

The Geochronology Laboratory made good progress with U-Pb zircon dating during the year. The most important outcome of this work is that the age of the Mount Isa Group, as determined from a Tuff Marker Bed within the Mount Isa orebody, is 1660 m.y. The Mud Tank Carbonatite, northeast of Alice Springs, was found to have crystallised 732 m.y. ago, and to have been deformed 320 m.y. ago (Alice Springs Orogeny). Rb-Sr work on the Newcastle Range Volcanics gives their age about 310 m.y. The Barnard Metamorphics, east of the Georgetown Inlier, are probably not of Precambrian age; they were metamorphosed and deformed during the late Palaeozoic.

Both geochronologists attended the Fourth International Conference on Geochronology in Colorado, and delivered papers there. One also spent five weeks by invitation at the Royal Ontario Museum, Toronto, investigating a new multi-sample capsule for dissolution of zircon, and using a new Pb-205 tracer in the mass-spectrometric analysis. The other visited leading geochronology laboratories in the USA and Europe, and investigated the Sm-Nd dating method with a view to its introduction in the joint ANU-BMR laboratory.

One geologist from the Section was in a group which visited the People's Republic of China. His main interest was in Precambrian geology and tectonics.

IRIAN JAYA GEOLOGICAL MAPPING SECTION

by

D.S. Trail

In July 1978 BMR became managing agent of an Australian Development Assistance Bureau project, to assist the government of Indonesia with systematic geological and geophysical mapping of Irian Jaya. A section was set up within Geological Branch and project members are held against its positions. Systematic 1:250 000 scale geological mapping was begun at the western end of Irian Jaya on 1 October by an Australian/Indonesian party using two light helicopters for transport; a brief geophysical reconnaissance will also be carried out in 1978. Results of reconnaissance geological surveys in 1976 and 1977, including two 1:250 000 geological sheets, are currently being prepared for publication in Indonesia.

MULTIDISCIPLINARY PROJECTS

by

A.R. Jensen

Over the last few years there has been an increasing number of multidisciplinary projects undertaken by BMR involving staff from two or more Branches. The various components of these projects have traditionally been programmed, controlled and reported as separate entities by each discipline-based Branch.

In order to overcome this problem, staff from various Branches involved in two multidisciplinary projects were, during 1978, drawn together into project teams. One of the projects is a study of the Georgina Basin and the basement rocks which underlie it; the other is a study of the McArthur Basin. E.C. Druce has been responsible for project co-ordination in the Georgina study and K.A. Plumb in the McArthur. Both studies aim at increasing our knowledge of the basins through detailed geological and geophysical research.

Studies in the Georgina project during 1978 comprise: analysis of the results of a major BMR seismic survey in the Toko Syncline; review of geophysical data to investigate the basement; interpretation of organic and inorganic geochemistry of samples from the southern parts of the basin; and sedimentological, stratigraphic and palaeontological research in Adelaidean and Lower Palaeozoic sequences. In addition the Georgina team conducted a workshop at the BMR Symposium in May at which progress results were presented.

Highlights of the Georgina studies include: the better delineation of the Mirrica Structure and estimation of a minimum closure of 700 m over an area of about 130 km^2; the recognition of four distinctive anomaly patterns within the basement underlying the Georgina Basin; the discovery of a small inlier of basement rocks near Sun Hill on the Mount Whelan Sheet area; the elucidation of Adelaidean stratigraphy in the area and recognition of six formations; the recognition of a karst surface between the Arrinthrunga Formation and the overlying Tomahawk Beds; the discovery of a conodont species which provides a better correlation of Australian and North American Tremadocian sequences; and the investigation of clasts of galena in the Adelaidean sequence.

Studies in the McArthur Basin during 1978 included: geological mapping of the Mallapunyah-Kilgour 1:100 000 Sheet area; sedimentological studies of the Wollogorang, Masterton, Mallapunyah and Dungaminnie Formations and the Amelia and Balbirini Dolomites; magneto-telluric and gravity investigations of the regional structure between the Wearyan Shelf and the Batten Trough; and an extensive sampling program to establish a palaeomagnetic reference section through the McArthur Group.

Principal results of the research include: the identification of a distinct break between the Wollogorang and Masterton Formations, and unconformities and karst features at several levels within the McArthur Group; the discovery of minor mineralisation associated with the newly identified karst features in the McArthur Group; the recognition of several magnetic reversals in the Umbolooga Subgroup of the McArthur Group; and the detection of several resistive layers which can be traced by the magneto-telluric method and used in broad structural analysis.

BAAS BECKING GEOBIOLOGICAL RESEARCH LABORATORY

by

A.R. Jensen

The Baas Becking Geobiological Research Laboratory, jointly sponsored by BMR, CSIRO and the Australian Mineral Industry Research Association, has continued during 1978 to investigate geobiological controls of base metal sulphide mineralisation. The research effort has been concentrated mainly on field studies in and around Spencer Gulf, SA, laboratory studies as an extension of the modern environment studies, and ore genesis studies in sedimentary basins.

The aim of the research within modern sedimentary environments such as Spencer Gulf is to determine the nature of those processes which, it is commonly proposed, have led to the formation and preservation of stratabound base metal sulphide mineralisation. In particular, this includes determination of the role of micro-organisms in sulphate reduction and in base metal mobilisation, transportation and precipitation. In addition, the studies aim to characterise environments where these processes take place so as to aid in the identification of similar environments in the stratigraphic record. It is not expected that the environments examined are analogues of ore-forming situations. They are simply places where the geobiological components of ore genesis models may be studied under natural conditions.

During 1978 research in Spencer Gulf involved studies of various intertidal and supratidal facies along the eastern margin of the Gulf including their sedimentology, hydrogeochemistry and microbiology. The sedimentological studies are aimed at producing a framework within which the other studies can be undertaken and ultimately related to investigations within the geological column. They have concentrated on the delineation of environments and the description of facies at various points in the northern part of the Gulf. The geochemical studies have involved investigations of the origin of the brines within the facies and of the processes controlling the distribution of heavy metals in the Gulf waters and sediment pile. Preliminary investigations of the brines have drawn attention to the important role of groundwaters in their origin. The metals study has indicated that the effluent from the nearby smelter has led to increases in the amounts of Pb and Zn in the sediments and that the metals are held in a relatively weakly complexed form which makes them available for participation in further reactions including conversion to sulphide.

The biological studies are aimed at assessing the controls of the biogenic evolution and distribution of sulphur in its various forms and in particular of hydrogen sulphide. Essential to this are the studies being undertaken on algal mats which are a prime factor in the production of energy for sulphate reduction. The productivity of mat-forming blue-green algae has therefore been monitored during the year and factors governing it have been assessed. At the same time, a series of experiments has been run which have determined the rates of sulphate reduction in algal mat sediments. The rates encountered are relatively high in comparison with those of other ecosystems and would be sufficient to account for a biogenic origin for a McArthur River-type ore body. Experiments are also being undertaken at Spencer Gulf to test the potential of intertidal algal mats to concentrate iron from seawater.

In addition to the studies in Spencer Gulf, during March a group from the Laboratory, together with geologists from the BMR McArthur and Georgina Basin teams and the Geological Survey of Western Australia, paid a brief visit to Shark Bay, W.A. This environment is characterised by many sabkha-like features and by a varied and extensive development of stromatolites. The visit complemented the studies being undertaken in Spencer Gulf, provided an opportunity for further integration of research interests of all those involved, and allowed an evaluation to be made of the potential of the area for research in the future.

The modern environment studies have also been supported by laboratory studies where experiments are being conducted to help assess the plausibility of biogeochemical models of sedimentary processes based on field evidence. The principal activity during 1978 has been the construction and use of a system of tanks filled with sediment and water and capable of simulating an evaporative sedimentary environment. The experiment is controlled and monitored by a complex set of electronic components. Early results indicate that the system is operating satisfactorily and that the sedimentary environment created resembles a natural ecosystem.

Research during 1978 has also continued into the origin and characteristics of various stratabound base metal sulphide deposits in the Adelaide Geosyncline and Stuart Shelf, S.A., and in the McArthur Basin, N.T. The studies have concentrated on Mount Gunson, Lake Dutton and Myall Creek areas on the Stuart Shelf, Kapunda in the Adelaide Geosyncline and Eastern Creek in the McArthur Basin. These studies are still progressing and final results are not yet available. Early results indicate that host rocks on the Stuart Shelf are enriched relative to the average shale in a number of trace elements, and that the sulphide in the deposits was originally biogenic. Trace element enrichment is not evident at Kapunda but isotopic data suggest a sedimentary source for the sulphide. Minor stable isotope studies have also been undertaken in the Pine Creek Geosyncline and on Archaean rocks in Western Australia.

Apart from the traditional Baas Becking Laboratory research into the origins of base metal sulphide deposits, some preliminary investigations have been made into the potential role of microbiological processes in the secondary recovery of petroleum from natural reservoirs.

SEDIMENTARY SECTION

Head: G.E. Wilford

PROVINCE STUDIES

BASIN SYNTHESES

STAFF: J. Smart, K.G. Grimes (GSQ), P.J. Kennewell, A.T. Wells, F.J. Moss (Geophysical Branch), M.J. Jackson, W.J.E. van de Graaff (GSWA), B.R. Senior

Additions to and revision of the first drafts of Bulletins and accompanying 1:500 000 or 1:1 000 000 scale geological maps synthesising and analysing the geology of the Wiso, Officer (WA), Ngalia, Carpentaria and Karumba Basins continued in 1978; the Bulletin on the Carpentaria and Karumba Basins was handed to the editors. Progress with the publication of the 1:250 000 scale geological maps and explanatory notes of the basins is given in frontispiece (1). Twenty three maps and explanatory notes were published during the year; a further 16 are in press.

The Ngalia Basin Bulletin will incorporate an assessment of the petroleum potential, using statistical methods; it was prepared in co-operation with Petroleum Exploration Branch. The results arising from magnetostratigraphic studies being undertaken jointly with P. Burek, Research School of Earth Sciences, ANU, will also be incorporated. Reversal patterns provide important constraints on correlations between late Proterozoic to early Palaeozoic Ngalia Basin units and those in the adjacent Georgina and Amadeus Basins. The palaeomagnetic work also indicates the nature of some Cainozoic movements in the area. The results of the synthesis of the geology of the Ngalia Basin were presented at the BMR Symposium in May.

A summary paper discussing the Jurassic to Cretaceous sedimentary basins of northeast Australia was prepared and presented by Senior at the Third Australian Geological Convention in Townsville. This paper will be published in a book, "The Geology of northeast Australia", and gives an account of the regional setting, evolution, structure and economic significance of the sedimentary sequences of the Carpentaria, Laura and northern Eromanga Basins.

Studies of the Georgina and McArthur Basins are reported on pages 203 to 229.

CANNING BASIN

SOURCE ROCKS AND THE HYDROCARBON POTENTIAL OF THE ONSHORE CANNING BASIN by R.V. Burne

STAFF: R.V. Burne, J. Gorter (formerly P.E.B.), J. Saxby (CSIRO)

Interpretation of the results of source rock analyses undertaken by CSIRO on material selected by J. Gorter prior to his resignation from BMR was undertaken. Although good source lithologies exist at suitable levels of organic metamorphism they are not at optimum levels in the sequence for migration into the best reservoir lithologies.

The analyses show that some areas in the south of the Canning Basin may be discounted from the point of view of their petroleum potential. The best potential reservoir lithology in the basin is the Tandalgoo Red Beds of the Kidson Sub Basin. This unit has porosities of up to 30%. However, both the Tandalgoo Red Beds and the underlying Carribuddy Formation have no known source potential. Similarly the Willara Sub Basin samples show low total organic carbon values for the Ordovician succession and there is an absence of suitable reservoir lithologies.

The source rock analyses provide encouraging evidence of Ordovician -sourced oil on the Broome Arch but the most promising areas have already been tested, without success owing to tight Ordovician formations or lack of seal in overlying Permian formations. Similar Ordovician-sourced prospects in the vicinity of Tappers Inlet have also been tested without success.

The upper Devonian Gogo Formation has good source potential, and the possibility of migration from this source into porous carbonates at the margin of the Fitzroy Graben provides some attractive prospects. However, the deeper parts of the formation are likely to be super-mature, and at this stage very little can be said about the degree of porosity development in the buried part of the Lennard Shelf reef trend. Our data show that upper Devonian carbonates north of the graben do not seem to have any source potential, though locally organic-rich fragments are implied by other analyses. South of the graben the lack of seal to the carbonates counter-balances their slightly more encouraging source potential.

Source rock analyses support the implication of widespread hydrocarbon shows, that the post-carbonate upper Devonian and lower Carboniferous sequence contains good source lithologies. However the prospectivity of this sequence is limited by the poor porosity and small size of potential Fairfield Group reservoirs, and by the lack of seal over much of the overlying Anderson Formation.

So far as the Permian succession is concerned, only the southeastern Fitzroy Graben appears to have favourable characteristics for the generation and retention of pooled hydrocarbons, sourced from the Noonkanbah Formation, in anticlinal structures. In areas of Triassic cover it might be hoped that these structures will not have suffered the breaching and flushing experienced by their counterparts in the northwestern part of the graben. Such accumulations might well be large, if the area of closure in anticlines in the northwest of the graben is any indication, but the remoteness of the area would probably mean that anything but a large pool of liquid hydrocarbons would be uneconomic to develop. Unfortunately the source rocks stratigraphically overlie the best potential Permian reservoirs of the Poole Sandstone and the Grant Formation, and it seems likely that the sandstones within the Noonkanbah Formation itself would form the prospective reservoir in this area.

MAPPING by R.R. Towner

STAFF: R.R. Towner (Party Leader), D.L. Gibson (part-time), D. Walton, L. Murray (BMR), R.W. Crowe (GSWA to 4/11/77)

The main objectives of the Canning Basin mapping project are to prepare 19 outstanding 1:250 000 scale geological maps accompanied by explanatory notes, to revise 12 first edition maps and notes which are now out of print, to prepare Records on each season's fieldwork and to publish a brief synthesis and 1:1 000 000 scale geological map of the whole basin, and papers on specific aspects of the geology. The project is a joint one with the Geological Survey of Western Australia. The reconnaissance geological field research was begun in 1972 and completed in 1977.

By October 1978, the results of the 1976 field season had been reported (Record 1978/8); photointerpretation and compilation of the remaining eleven Sheet areas in the West Canning Basin was completed; seven explanatory notes and maps had been published; a further 12 explanatory notes and maps were with the editors; and one other explanatory note and map was in the final stages of preparation.

EROMANGA BASIN HYDROCARBONS

by

B.R. Senior

STAFF: B.R. Senior, M.A. Habermehl

An investigation into the significance of linear features interpreted from Landsat data was commenced covering southwest Queensland. These data are being compared with reconnaissance seismic interpretations and with groundwater flow patterns with the objective of delineating areas for further study for petroleum search.

Previous geological and photogeological work identified a pronounced northeast-trending structural grain. Examination of Landsat imagery and recently aquired RC9 aerial photography has revealed a second structural system which trends north-northwest.

The Great Artesian Basin regional groundwater flow was probably northerly in late Mesozoic to early Tertiary times, based on broad palaeographic reconstructions. Bu the Miocene this flow pattern changed to a southwesterly one owing to uplift around and locally within the basin. An understanding of the geological structure and hydrogeological data could indicate areas of interest for petroleum search. Basin-wide movement of groundwater has flushed large low amplitude folds but might also be the mechanism for moving hydrocarbons into certain types of structures. Of interest are structures at right angles to the principal groundwater flow direction and include faults, folds and monoclines.

Some water bore data indicate stagnant or semi-stagnant groundwater conditions. However along the axis of the Eromanga Basin where the sequence is 1500 to 3000 m thick, and hence has the greatest petroleum potential, there are very few water bores.

Source rock analyses are being carried out to determine the maturity of the Eromanga Basin sequence and to determine if any hydrocarbon generation predates or postdates the mid-Tertiary structural events.

LACHLAN FOLD BELT (CANBERRA AREA)

by

M. Owen and R.S. Abell

STAFF: M. Owen, D. Wyborn, R.S. Abell

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

During 1978, the descriptive Bulletin on the Tantangara and Bridabella 1:100 000 Sheets was submitted for editing, fieldwork on the Canberra 1:100 000 Sheet area was completed, and about three-quarters of the Araluen 1:100 000 Sheet area was mapped.

TANTANGARA-BRINDABELLA SHEET AREAS by M. Owen

The descriptive Bulletin was passed to the editorial section, while preparation of the 1st edition coloured maps is well advanced, fair drawing and colour design work having been completed.

ARALUEN SHEET AREA by M. Owen

Systematic field research commenced in early October 1977, and by the end of October 1978 about three-quarters of the sheet had been examined using colour airphotographs at 1:25 000 scale. Fieldwork is expected to be completed by early 1979.

As a result of the work already done a broad outline of the geology of the area can be given. The earliest rocks so far recognized are of Late Ordovician age, and consist of a flysch sequence of rather distal aspect, typical of much of the Ordovician throughout the Lachlan Fold Belt. No evidence of volcanic activity in the Ordovician has been found, though locally there are proximal turbidite sequences.

The Ordovician is overlain, apparently with only a minor structural break, by an upper Silurian shallow marine sequence which extends northwards along the Minuma Range from Bendethera to Wyanbene and Cleatmore. Much of this sequence is composed of mudstone and quartz sandstone, but locally carbonate lenses have developed which have yielded Ludlovian conodonts. Conformably overlying this marine sequence are terrestial acid volcanic piles, cropping out in two separate areas. That to the west of the Minuma Range, in the Shoalhaven Valley, is the Long Flat volcanics, dominated by dacitic and rhyolitic ignimbrites with co-magmatic shallow-level intrusive porphyries. The previously undescribed and as yet un-named volcanics east of the Minuma Range are, by contrast, formed predominantly of air-fall tuff and agglomerate, with only local development of rhyolitic lava and ignimbrite.

The Ordovician and upper Silurian sequences have been extensively intruded by granites, possibly in two phases. In the extreme west of the area a series of strongly foliated granodiorites definitely predates the major Bowning Fold Episode. Elsewhere, granites such as the Boro and Braidwood Granites appear to post-date the folding.

All of the granites in the area have been intruded by dominantly east-west oriented basic dyke swarms, those in the Boro Granite being particularly widespread. Some individual dykes have been traced for up to 10 km. An Early to Middle Devonian age for them is considered likely, since no dykes have been found intruding upper Devonian sedimentary strata.

Upper Devonian rocks occur in two meridional belts on the Araluen Sheet, the Minuma Range Group in the west, and an eastern belt which, though yet to be studied in detail, is known to overlie rhyolitic and basaltic lavas and to contain common marine invertebrate faunas. The Minuma Range Group is strongly unconformable over older units, and dips gently to the west. It commences with a basal conglomerate which is very variable in thickness, ranging from 0 to 120 m, followed in the south by two deltaic cycles of interbedded shale and sandstone coarsening upwards into conglomerate, and overlain by a terrestial red-bed sequence. North of Wyanbene the deltaic cycles appear to pass laterally into a coarse shallow marine sandstone with local conglomeratic beds. Marine fossils are very rare in the southern deltaic sequence but become more common in the north, near Majors Creek.

The results of a soil and stream sediment geochemical survey undertaken concurrently with the mapping are outlined on pages 184 and 185.

CANBERRA SHEET AREA by R.S. Abell

Fieldwork was completed in April. Eight 1:25 000 field data sheets will be broadly interpreted and then made available during mid-1979 as a BMR Record. These sheets will then be compiled to form a preliminary 1:100 000 geological map planned to be available early in 1980.

Mapping has shown it is impossible to subdivide the Ordovician into stratigraphic units owing to a lack of marker lithologies; it forms a thick distal flysch sequence identified with Opik's Pittman Formation. West of Gundaroo the occurrence of feldspar and scour structures in arenite units suggests a more proximal flysch. At this stage it is uncertain whether the named black shale members can be correlated as one unit, i.e. Acton Shale.

For the upper Silurian acid volcanics around Canberra it is proposed to adopt the stratigraphy established for the Tantangara-Bridabella 1:100 000 Sheets. The main stratigraphic subdivisions are based on chemical analyses and mineral phases from thin section; these rocks cannot be adequately sub-divided on field features. It is now clear that the volcanic sequence in the Canberra Sheet area is a subaerial ignimbrite pile interfingered with marine sediments. The Painter Porphyry (to be called the Painter Volcanics) is now regarded as a volcanic unit.

The middle to upper Silurian succession in the Captains Flat trough has been complexly folded into steeply plunging antiforms and synforms. Some of the stratigraphic units (Copper Creek Shale and Kohinoor Volcanics) originally established at Captains Flats mine cannot be recognised with certainty to the north, as has been done by some workers. Although the stratigraphy has finally to be elucidated it is possible that a regional correlation may exist with the Silurian succession already established by Felton and her colleagues for the Braidwood 1:100 000 Sheet.

The Tertiary is represented by high-level ferruginous quartz cong-lomerates. East of Gundaroo they probably represent old river gravels of earlier headwaters of the Yass River. Around Hoskinstown similar conglomer-ates probably relate to an older phase of the Molonglo drainage system. The gravels preserve a land surface representing a pre-Tertiary peneplain.

The Quaternary is represented mainly by alluvial and lacustrine deposits, and windblown sand. Colluvial deposits are well exposed at Nanima, Black Mountain and Lanyon, and rest directly on a rock base without an intervening soil profile. They consist of subangular fragments of the local bedrock, suggesting only minimal transport probably under cold arid climatic conditions.

Most of the granites investigated appear to be I-type. The Sutton Granite has a contact aureole, the 'spotting' in some downward-facing turbidite units giving the appearance of 'reverse grading' in the argillaceous units.

North of Canberra lenticular outcrops of calc-silicate rocks have probably originated by contact metamorphism from buried granite intrusions. Along Red Hill ridge (Canberra) similar rocks have been produced by contact metamorphism from a quartz diorite underlying the Federal Golf Course. It is likely that this intrusion is the cause of a large magnetic anomaly which underlies the area and trends southeast towards Queanbeyan. The Mugga Porphyry, originally thought to be an intrusive rock and locally the cause of this metamorphism, is now considered a volcanic flow sequence.

Numerous north-trending discontinuous bodies of foliated quartz feldspar porphyry are exposed in Ordovician flysch outcropping along the Lake George escarpment, and in a belt east of the Bungendore-Hoskinstown road. These porphyries are probably offshoots of a more extensive granite body at depth.

Basic intrusions are widespread in time and areal distribution. They can be grouped into those intruded before and those intruded after the second phase of regional folding (F2). <u>Pre-F_2</u> - these include (a) amphibolites and hornblende gabbros of the Lochart Basic Igneous Complex and associated bodies of altered dolerite and gabbro in nearby country rocks; (b) epidiorites (metadolerites) with a strong northerly foliation, outcropping along the northern edge of Lake George. <u>Post-F_2</u> basic rocks (most of which are Tertiary in age) have two distinct trends; northerly and northwesterly. They are unfoliated, range from dolerite to gabbro, trend parallel to major lineament directions and cut all Palaeozoic sediments, acid volcanics, acid intrusions and Pre-F_2 basic rocks.

Features interpreted from ERTS imagery at 1:250 000 scale suggest that two movements have taken place along the Lake George Fault zone. In the vicinity of Lake George the scarp is defined by a strong north-northwesterly trending lineament which can be traced south across the Bungendore plain to Hoskinstown; it defines a line of Cainozoic faulting and supports a youthful drainage system. About 4 km west of Bundendore the scarp changes direction by 30° and trends southwards towards Primrose Valley. Along this section the scarp is less well defined and carries a more mature drainage pattern; this section of the scarp probably denotes a zone of earlier reverse faulting. A drill core record from lacustrine sediments at the northern end of Lake George, obtained by G. Singh et al. of A.N.U., has been dated as early Pliocene or late Miocene, which places the age of the most recent movements along Lake George Fault as considerably older than the Late Miocene.

BROKEN HILL REGIONAL STUDY

STAFF: A.N. Yeates

A regional study of the Precambrian metamorphic rocks of the Broken Hill-Euriowie Tank areas in far west NSW was begun in June 1976 at the University of New England, Armidale, financed by a Commonwealth Postgraduate Award, and is now being completed part-time.

The main objective of the project is to study the regional geology, the ultimate aim being to determine the pre-metamorphic nature of the rocks and to attempt a reconstruction of the Precambrian palaeogeography. Concurrently with the investigation, a review of all known available literature was undertaken and is continuing.

It is hoped that this study, when completed, will add to the understanding of the geological history of the district and that it will provide a clearer understanding of the setting of the Broken Hill ore environment, and a better basis for mineral exploration in this and other metamorphic terrains.

AUSTRALIA-WIDE STUDIES

CAINOZOIC WEATHERING

STAFF: B.R. Senior

Work continued on a series of publications discussing parent rocks and weathered profiles in southwest Queensland. Those published include a method of dating weathered profiles using palaeomagnetism (Idnurm & Senior, 1978), and the geology and magnetic characteristics of southwest Queensland precious opal deposits (Senior et al., 1977). Manuscripts are complete for a further two papers which discuss a proposed method of defining weathered rocks and its application to regional geological mapping (Senior & Mabbutt, in prep.), and clay-mineralogy, geochemistry and petrology of weathered and parent rocks in southwest Queensland (Senior, in prep.).

The southwest Queensland study has provided a framework on which studies of other weathered rock terrains can be based. Future work is planned for detailed studies of 'key areas' throughout Australia where weathered profiles and associated Cainozoic rocks are widespread.

In 1977, oriented specimens of weathered rock were collected along a traverse between Brisbane, Alice Springs and Darwin. These have now been drilled and magnetic remanence values calculated but as yet no interpretations have been made. The aim of this study is to try and correlate and determine the timing of weathering for the various types of weathered profiles in Queensland and the Northern Territory.

EVAPORITES IN AUSTRALIA

STAFF: A.T. Wells

Work commenced on processing a Record on Evaporites in Australia to a form suitable for publication as a Bulletin. Additional new information was added where necessary.

Wells contributed to a seminar on Australian evaporites at the Economic Geology Group of Research School of Earth Sciences, A.N.U.

HYDROGEOLOGICAL STUDIES

HYDROGEOLOGY OF THE GREAT ARTESIAN BASIN

by

M.A. Habermehl

STAFF: M.A. Habermehl, G.E. Seidel

The Great Artesian Basin project consists of a hydrogeological study of this multi-aquifer confined groundwater basin, and the development and application of a mathematical, computer-based model to simulate the groundwater hydrodynamics (GABHYD).

The GABHYD model is used as a predictive tool for regional groundwater management and provides responses to various alternative management schemes. It also enables a basinwide assessment of the artesian groundwater resources of the Great Artesian Basin to be made.

From 1972 to 1974, and with assistance from staff provided by BRGM-Australia, geological, geophysical and hydrological data from BMR and State Geological Surveys were compiled, transcribed and computer processed and stored. Analysis of the hydrogeological information resulted in the definition of a prototype of the Great Artesian Basin, which combines the many aquifers in the Mesozoic sedimentary sequence (consisting of continental deposited quartzose sandstones of Triassic, Jurassic and Cretaceous age) into two confined aquifers, and further two confining beds (Cretaceous mudstone and siltstone) and a near-surface watertable. The latter approximates a constant head boundary compared with the changing heads of the confined aquifers.

The prototype forms the link between the real basin configuration and the computer model. The GABHYD model operates on a square grid with a separation of 25 km between the gridlines; the part of the Great Artesian Basin studied fits into a rectangle containing 67 gridlines from west to east and 58 gridlines from south to north. The prototype defines the geometry of the aquifers and for each of the two confined aquifers and on each intersection of gridlines (or gridnodes) the model prototype defines the hydraulic parameters (horizontal transmissivites, vertical leakage factors, storativities) and the state variables (potentials, discharges). For the watertable the potentials only are required. Horizontal boundaries of the model are defined as impermeable boundaries or as permeable boundaries defined by prescribed constant potentials. All information is derived from data recorded in the GAB-ADP system.

The digital computer model GABHYD is based on finite difference approximations of the Hantush approach for leaky aquifers. The model determines for each mode of each confined aquifer the complete waterbalance. Model output consists of all potentials and discharges for each major time step and each gridnode. The GABHYD model replaced the original GABSIM model, and consists of a group of computer programs developed during 1975 to 1977. This program system is used to generate the initial data base, to calibrate the model using a newly developed direct method, run the mode over an historic or future development period with different management options, and tabulate and plot the results. Model calibration was completed during 1977 and some application runs carried out.

During 1978

- The GABHYD model program system was further expanded
- The GABHYD model was recalibrated
- Application runs were made including a proposed development in South Australia
- A workshop on the GABHYD model was held in August 1978
- Documentation continued of the hydrogeology of the Great Artesian Basin and of the GABHYD computer programs and operating systems.

GABHYD PROGRAMS EXPANSION

Computer terminal operating systems, for running the model, which are integrated with a terminal operating system to analyse the model output, were designed and programmed. All stages of the model application from the preparation of input data, including the selected management options, to the analysis and final presentation of results are accessible through the interactive terminal system. The interactive console operating system puts questions to the user and automatically runs the relevant programs using data compiled from the replies obtained from the user. No previous experience with computers is required to use this system. Output presentation options include:

- small and large maps produced by lineprinter using alphanumerics
- line printer tabulation of data versus time
- contour plot of a data array on a small line plotter (25 cm width), large plotter (70 cm width) or on 35 mm photographic film
- perspective simulated three-dimensional drawing or contour map drawing on 25 cm or 70 cm line plotters or 35 mm film

RECALIBRATION OF THE GABHYD MODEL

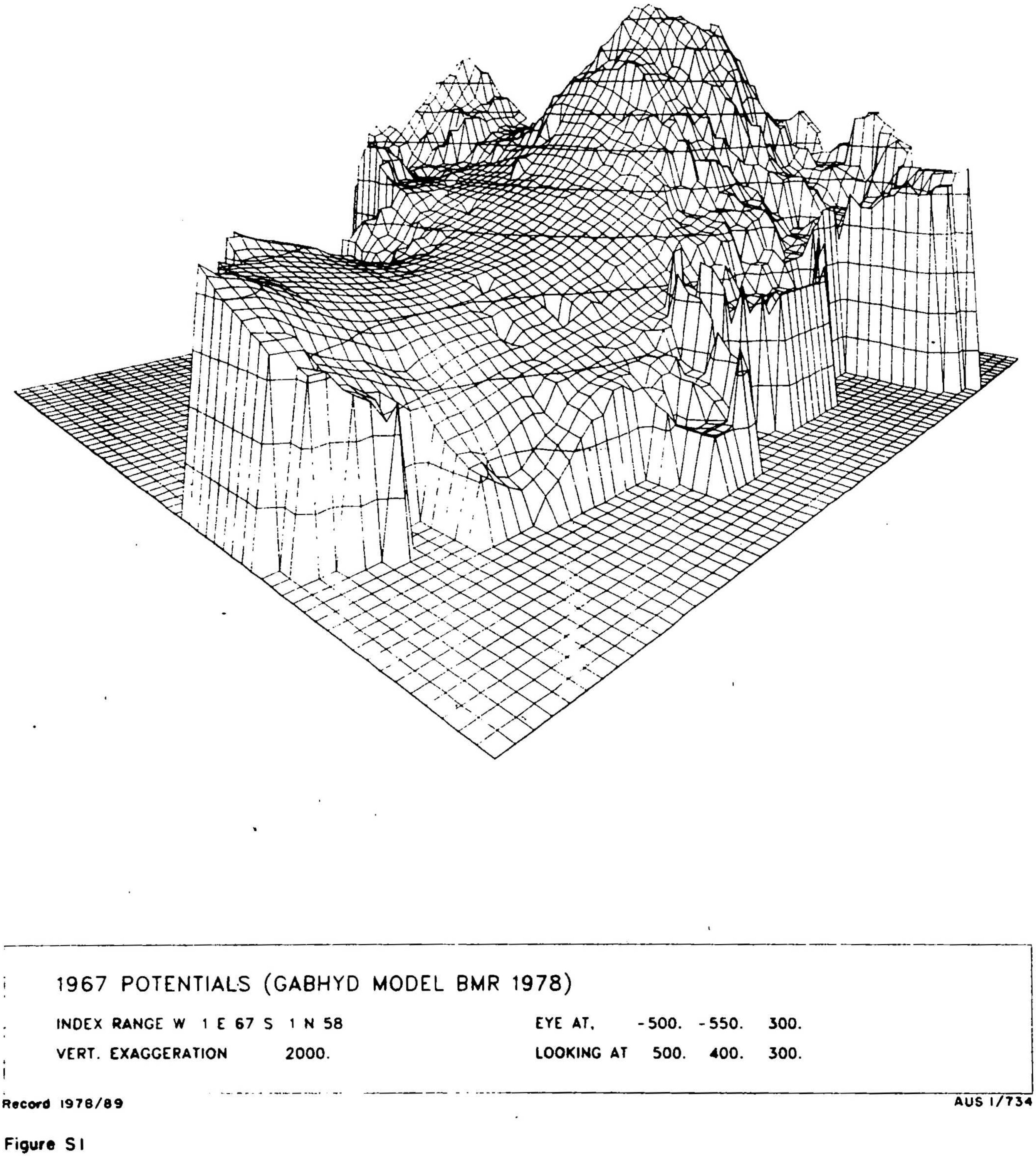
Following recompilation of recorded discharge and potential data files, which included data from South Australia not previously present, a recalibration of the GABHYD model was carried out.

Confined aquifer 2 in the mode (corresponding with Jurassic aquifers) is the main aquifer of the model. Only a few data are available for confined aquifer 1 (corresponding with Cretaceous aquifers) and no detailed calibration could be attempted for it. Calibration is by a direct method and directional transmissivities are determined from the recorded potential data and from boundary conditions which include recorded well discharges.

GABHYD MODEL APPLICATION

Application of the model included predictions on continued, unchanged development from present artificial discharge conditions (i.e. no new flowing artesian waterwells being drilled in the basin) to the year 2000. Fig. S1 shows the resultant potentiometric surface. (To determine the actual potential values, a temperature correction has to be applied to individual values, as the model data and results are based on pure water at 15^{o}C).

Other application runs dealt with results of historical development and with a proposed development in the South Australian part of the basin. An assumption was made that 900 l/sec would be extracted from a specific area from 1980 onwards. Detailed drawdown data against time, the extent of the difference in potentials and the effects on the immediate area and on other parts of the basin from 1980 to 2000 were produced in the form of contour maps at different scales.



Record 1978/89 AUS 1/734

Figure S1

Perspective simulated three-dimensional drawing of the potentiometric surface and contours of potential of confined aquifer 2 (Jurassic aquifers) of the Great Artesian Basin during 1967. Contour interval is 40m.
The eye is at the location of 500km W, 550km S and 300m up from the closest (SW) gridcorner, and looking towards the northeast. The figure was automatically produced by computer from output of the GABHYD model.

GABHYD WORKSHOP

The workshop on the GABHYD groundwater model of the Great Artesian Basin and its application was held at BMR from 14 to 16 August 1978. It dealt with the hydrogeology of the basin, the model prototype, mode discretisation and definition of variables, model calibration and comparison of calibration results with independent data. A description of the model programs, the running instructions for the model and output display package was given. During several practical sessions the computer terminal was used to prepare and run the model, including a hypothetical case in South Australia, and to demonstrate and apply the output display package.

The ten participants represented the Geological Surveys and Water Authorities of Queensland, New South Wales, South Australia, the Northern Territory and Victoria.

DOCUMENTATION

The first draft of the report Hydrogeology of the Great Artesian Basin was completed and following initial editing returned for alterations.

Documentation continued on data generation, calibration, model application and output computer programs of the GABHYD simulation model system. Writing and editing of the Record - 'Hydraulic calibration of the GABHYD model of the Great Artesian Basin' - was completed, but figures still await drafting. Writing and editing of the Record-Operating manual for the GABHYD model was also completed. Figures for this manual were drafted by computer using a newly designed program. This program is operated by answering questions on the interactive terminal and is suitable for general use by persons without experience on the computer. An operating manual for this program is being prepared.

A paper entitled - 'Groundwater resources of the Great Artesian Basin' was prepared for presentation during the Australian Academy of Technological Sciences Symposium on The Land and water resources of Australia - Dynamics of utilisation, in Sydney, from 30 October to 1 November 1978.

WIRE-LINE LOGGING OF WATERWELLS IN THE GREAT ARTESIAN BASIN

by

M.A. Habermehl

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

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

All existing waterwells in the basin contain steel casing for most or all of their total depths, and wire-line logs are therefore mainly restricted to nuclear logs. Usually the logs obtained during this program include natural gamma-ray and neutron, as well as differential temperature, temperature and casing collar locator logs, and from some flowing artesian wells flow-meter logs. If sufficient uncased, open hole occurs, spontaneous potential, resistivity and caliper logs are also run.

The logs can be interpreted to determine the lithology, geometry and porosity of lithological units, to identify and correlate stratigraphic units and waterbearing beds, to define the source and movement of water discharged by the aquifers and to determine construction and corrosion details of the casing in the well.

Data from about 1250 flowing and non-flowing artesian waterwells and some converted petroleum exploration wells in Queensland, New South Wales and the Northern Territory, which were logged by BMR and its contractors during the period from 1960 to 1975, were transcribed onto transfer sheets and punch cards prepared and completed. These data will subsequently be incorporated into the GAB-ADP system, after which computer processing and retrieval will be possible. Listings for distribution will probably be prepared on microfiche.

During 1978, results of chemical analyses of water samples from the wells logged were added, together with barometric data used to determine ground-elevations of well sites. The wire-line logs were checked for the completeness of drillers' logs, and the latter added, including rock descriptions and water levels recorded during drilling.

Basic well and log data of waterwells logged by the Geological Surveys of New South Wales (about 235) and South Australia (17) in their parts of the Great Artesian Basin were also recorded and checked.

ISOTOPE HYDROLOGY OF THE GREAT ARTESIAN BASIN

by

M.A. Habermehl

Environmental isotopes in the groundwater of the principal Jurassic aquifers of the Great Artesian Basin are being studied by the Isotope Division of the Australian Atomic Energy Commission in collaboration with BMR.

The initial aim of the study was to provide an independent check on derived hydraulic data, determine the residence time and rate of flow of the water through the aquifers and elucidate its origin.

Water samples from wells are analysed where appropriate for the naturally occurring radioactive isotope of carbon, ^{14}C, the ratio of the stable isotopes of carbon $^{13}C/^{12}C$, the hydrogen isotope ratio D/H, the oxygen isotope ratio $^{18}O/^{16}O$, the uranium isotope ratio $^{238}U/^{234}U$ and ^{226}Ra, and the chlorine isotope ^{36}Cl. Further detailed analyses are made of the chemical constituents. The wells sampled were selected on hydrogeological criteria by BMR and usually located along flowlines of the artesian groundwater in the main Jurassic aquifers, in a pattern radiating outwards from the recharge areas.

During 1974 and 1975 officers of AAEC collected samples from 82 flowing and non-flowing artesian wells in the northeastern, east-central and south-central parts of the basin. During 1976 a joint AAEC-BMR party sampled 24 flowing artesian waterwells and moundsprings in the southwestern part of the basin. During September 1978 a combined AAEC-BMR party sampled 30 flowing artesian waterwells in the southeastern part of the basin.

The average velocity of groundwater movement in the main Jurassic aquifers in the eastern marginal areas as calculated from hydrogeological data amounts to about 1 to 5 m/year. Isotope analysis confirms this. However these values for the rate of flow of artesian groundwater restricts the application of ^{14}C dating. Residence time determinations with this isotope are limited to relative short distances from the recharge areas of the aquifers, as ^{14}C has a half-life time of 5730 years and the method can be used only for water with ages up to about 30 000-40 000 years. Studies are being carried out to evaluate the application of ^{36}Cl which has a half-life time of about 400 000 years. Use of this isotope would be more suitable for the dating of the very old groundwater which has moved over considerable distances in the Great Artesian Basin.

Analysis of hydrogeological, hydrochemical and isotope ratios show that highly compatible results are obtained. The D/H and ^{18}O results unequivocally show that the artesian water is of meteoric origin. Observed systematic variations in chloride levels of water samples from the north-eastern and eastern areas probably reflect variations in the rate of infiltration of recycled salt throughout the late Quaternary (300 000 years). The minimum and maximum in the chloride curve correlate with the last glacial and interglacial period respectively. Bicarbonate ion levels are perturbed by dissolution of carbonate minerals in the aquifer material; about 0.1 percent of the aquifer material would have been dissolved since mid-Tertiary. D/H ratios were extremely constant, and no evidence is present for exchange of oxygen between water and the host rock despite the long contact periods, sometimes at elevated temperatures. A ^{226}Ra, ^{238}U survey showed that radium is frequently in excess despite extensive leaching since Tertiary times and the fact that the time scales associated with the transport of water are large compared with the half life of ^{226}Ra.

Some interpretations of results from analyses of samples from wells in the eastern part of the basin were published in a joint AAEC-BMR paper - 'Aspects of the isotope hydrology of the Great Artesian Basin, Australia', prepared for the International Symposium on Isotope Hydrology of the International Atomic Energy Agency in cooperation with the United Nations Educational, Scientific and Cultural Organization at Neuherberg, Federal Republic of Germany, 19 to 23 June 1978.

SOIL SALINITY STUDY IN NORTHEAST THAILAND

by

M.A. Habermehl

A feasibility study to appraise the proposal for a soil salinity study in the northeast region of Thailand was carried out by R.H. Gunn (soil scientist - CSIRO) and M.A. Habermehl (hydrogeologist - BMR) for the Australian Development Assistant Bureau.

As part of its program to increase rice production in northeast Thailand, the Thai Government has requested that technical assistance be provided to study salt-affected areas and to assess the possibilities of reclamation and improvement. The objective and scope of the experts' visit was to determine the precise nature of experts, training and equipment necessary to ensure that the project achieves its objectives.

Habermehl was engaged by ADAB from 28 January to 10 March 1978 and visited Thailand from 28 January to 26 February 1978. Information on available data on soils, geology, groundwater, topographic maps, aerial photographs, Landsat imagery and other relevant information were collected during discussions with several Thai government departments, UN organizations and universities in Bangkok during the first and last week of the visit. A field trip traversing about 4000 km in northeast Thailand was undertaken from 6 to 19 February 1978 and included areas near Udon Thani, Sakon Nakhon, Khon Kaen, Kalasin, Roi Et, Suwannaphum, Chaiyaphum and Nakhon Ratchasima (Khorat). Accompanied by two Thai scientists, the occurrence and approximate extent of salt-affected soils was assessed. Salt efflorescence and saline soils occur in areas underlain by the Salt Formation, and generally in topographic lows and at the bottom parts of slopes of hills or undulations.

The Salt Formation forms the upper part of a Mesozoic sedimentary sequence which occurs in the Khorat Basin and Sakon Nakhon Basin of the Khorat Plateau. The formation consists of sandy shale, siltstone and sandstone of about 600 m thickness, and contains gypsum and anhydrite in beds up to 15 m in thickness and rock salt (halite) of 250 m or more thick. Some thick beds of salt may be continuous for 100 km in the subsurface, but rock salt, gypsum and anhydrite also occur as lenses and are disseminated throughout the area. Depth to salt beds or lenses is variable and ranges from 60 m to more than several hundreds of metres. Weathering of the rocks in the upper part of the Salt Formation during the Tertiary has removed some of the salt, but seasonal upwards movement of groundwater and lateral seepage and possibly artesian upwards leakage of saline groundwater probably causes salinisation. Changes in hydrologic conditions following clearing of natural vegetation to establish rainfed padi rice generally resulted in saline seepages of groundwater on middle and lower slopes of low ridges and undulations and on adjacent plains. Groundwater dissolves, transports and deposits most of the salts in the area.

Soils are generally sandy and silty. Groundwater tables (as measured during the visit which took place during the dry season) were from 1 to 5 m below the groundsurface. Groundwater salinity, measured in wells and pits ranged from several hundred to 65 000 microSiemens per cm. A 12-channel portable seismograph was used in some locations to determine the thickness of the weathered part of the Salt Formation.

During the last week of the visit additional discussions were held with Thai officials and preliminary conclusions and recommendations about the visit and the proposed study and research sites formulated. Following the return to Australia, a joint report by Gunn and Habermehl was prepared and submitted to ADAB. This report - 'Feasibility study of soil salinity in Northeast Thailand' - was issued and distributed by ADAB during July 1978.

The conclusions and recommendations in the report include the recommendation of a technical assistance program, mainly based on detailed surveys and research over a 2-year period in selected parts of a 2500 km^2 area. The area is representative of other salt-affected landscapes in the region, and detailed topographic, soil and groundwater surveys could determine the nature, origin and seasonal movement of soluble salts in selected landscapes. Emphasis is to be given to the prevention of secondary salinisation but some work on the reclamation of salt-affected soils should be initiated. Research should also be carried out on salt-affected soils and saline groundwater in planned and already being constructed irrigation areas.

Other recommendations dealt with work on crop tolerance to salinity, requirements for and type of expertise, aspects of surveys and laboratory work to be carried out as well as equipment required, and counterpart training.

MISCELLANEOUS ACTIVITIES

by

M.A. Habermehl

ENVIRONMENTAL GEOLOGY

Comments were prepared on hydrogeological aspects of the report 'Wagerup Alumina Project, Environmental and Management Programme' by ALCOA-WA and on groundwater aspects of the 'Draft Environmental Impact Statement and Environmental Review and Management Programme Yeelirrie Uranium Project WA' of Western Mining Corp. Ltd for incorporation in BMR Professional Opinions.

AWRC-TCUW MEETINGS

Habermehl attended as an observer the meetings of the Australian Water Resources Council - Technical Committee on Underground Water - Subcommittee on Standards of presentation of hydrogeological data. Topics discussed included a catalogue of groundwater data, and hydrogeological maps, on 17 and 18 August 1978 respectively.

HYDROGEOLOGY OF THE MURRAY BASIN

Preliminary discussions were held by BMR officers with State representatives during AWRC-TCUW meetings in 1977 and 1978 and attendance by Habermehl at the Australian Society of Soil Science Inc. Symposium on 'The hydrogeology of the Riverine Plain of southeast-Australia', at Griffith NSW from 28 to 30 July 1977, and the Royal Society of Victoria Symposium on 'The Murray-Darling River System' at Melbourne on 13 October 1977, following these, and internal BMR discussions, possibilities of a hydrogeological study of the Murray Basin were further explored. G.E. Wilford and M.A. Habermehl visited the Geological Surveys and Water Authorities of New South Wales, Victoria and South Australia during September 1978 for preliminary discussions on a possible joint Commonwealth/State study of the Murray Basin. Specific topics discussed included the formulation of a program for joint studies, data availability, current and planned future work programmes and the possible contribution of each organisation to co-operative studies. From these discussions a more specific proposal will be prepared which will be considered by a meeting of all organisations involved.

PHOTOGEOLOGY AND REMOTE SENSING

by

C.J. Simpson

STAFF: C.J. Simpson, W.J. Perry, A. Warnes (Part-time)

BMR FIELD RESEARCH

The Group carried out regional photo-interpretation to assist field personnel in the planning and execution of field work in the following BMR projects (more detailed results appear under individual project reports).

McARTHUR BASIN PROJECT

Colour airphotographs (1:25 000 scale) supplemented by black and white RC9 (1:84 000 scale) were used to interpret selected areas within the Mallapunyah and OT Downs 1:100 000 Sheet areas. Emphasis was placed on detection of faults. Because of their lithological similarity, differentiation of the various dolomitic units within the Proterozoic McArthur Group is particularly difficult on airphoto criteria alone. Simpson worked with the field party in August.

CLONCURRY-MOUNT ISA PROJECT

Warnes (TTO) annotated access and drainage on the Mount Oxide and half of the Ardmore 1:25 000 scale colour photographs prior to field work. Perry completed an interpretation of the Ardmore photographs and compiled the data on the 1:100 000 photo-index sheet prior to field work. The compilation drew attention to several problems of correlation requiring field observations for their resolution.

GEORGINA BASIN PROJECT

Simpson's involvement in the project continued from 1977. Field data collected in that year on the Adam 1:100 000 Sheet area were collated and prepared for preliminary drafting. Simpson delivered a lecture on the structure of the southern margin of the basin to the Georgina Basin workshop (4 May). Current data suggest the Toomba Fault is a reverse fault arising from north-south compression and resulting in the Proterozoic rocks on the western side being in places overthrust onto Palaeozoic sediments.

REMOTE SENSING

LANDSAT

The Group continued their research into Landsat with emphasis on investigating applications of the data to BMR projects. CSIRO computer-enhanced imagery of the McArthur Basin and southwestern Georgina Basin was acquired to prepare mosaics for study of the major structural features in each area.

Collaborative work with the ADP Group continued in order to develop facilities for computer manipulation of Landsat computer-compatible tapes (CCT's). Several programs for enhancement and display of CCT data are now operational. CSIRO facilities at North Ryde and Canberra were used to investigate the potential and capabilities of computer analysis.

Simpson attended the Pecora III Symposium at Sioux Falls, South Dakota from 30 October to 2 November 1977. An article entitled 'Landsat: developing techniques and applications in mineral and petroleum exploration', which included discussion on several of the papers presented at that symposium, was published (BMR Journal 3(3) 181-192).

Existing publications confirm that Landsat data, when logically applied, can provide useful complementary information to assist conventional techniques of mineral and petroleum exploration.

W.J. Perry (Group Supervisor) and C. Simpson in association with A.A. Green and J.F. Huntington of CSIRO Division of Mineral Physics; K.N. O'Sullivan of CRA Exploration Pty Ltd; and J.G. Wilson of R.F. Loxton Hunting and Associates prepared course notes and made arrangements for the Australian Mineral Foundation workshop course 'Geological application of Landsat data'. The course will be held in Canberra 27 November-2 December 1978.

OTHER ACTIVITIES

The Group continued to provide display and instruction on photogeology and remote sensing. Delegations from China, Royal Melbourne Institute of Technology and Bruce TAFE college visited the group.

Simpson delivered a lecture on 'Remote Sensing' to the 'Sixth Underground Water School' held by the Australian Mineral Foundation, Adelaide.

As a result of a request to BMR from the Sydney Stock Exchange, Perry provided the Exchange with technical advice on the work of a member company in the application of Landsat data to mineral exploration.

MARINE GEOLOGY AND COASTAL STUDIES

CO-OPERATIVE PROJECTS WITH FEDERAL REPUBLIC OF GERMANY

by

N.F. Exon

SULU SEA SEDIMENTATION

In 1977 RV Valdivia recovered 46 cores, occupied two hydrographic stations and ran several bathymetric profiles in the Sulu Sea, with the object of better understanding the style of sedimentation in a deep, virtually land-locked marine basin in a tectonically active area. In October and November 1977 N.F. Exon was at Kiel University aiding in the interpretation of the data, and in 1978 he helped prepare a cruise report which was submitted to CCOP for inclusion in their Technical Bulletin series. He was senior author of another paper dealing with pelagic and turbidite sedimentation in the Sulu Sea.

The Sulu Sea is roughly rectangular with its long axis trending northeast, and covers about 250 000 km^2 (Fig. S2). The maximum depths of nearly 5000 m are in the Sulu Sea Deep in the southeast, which is separated

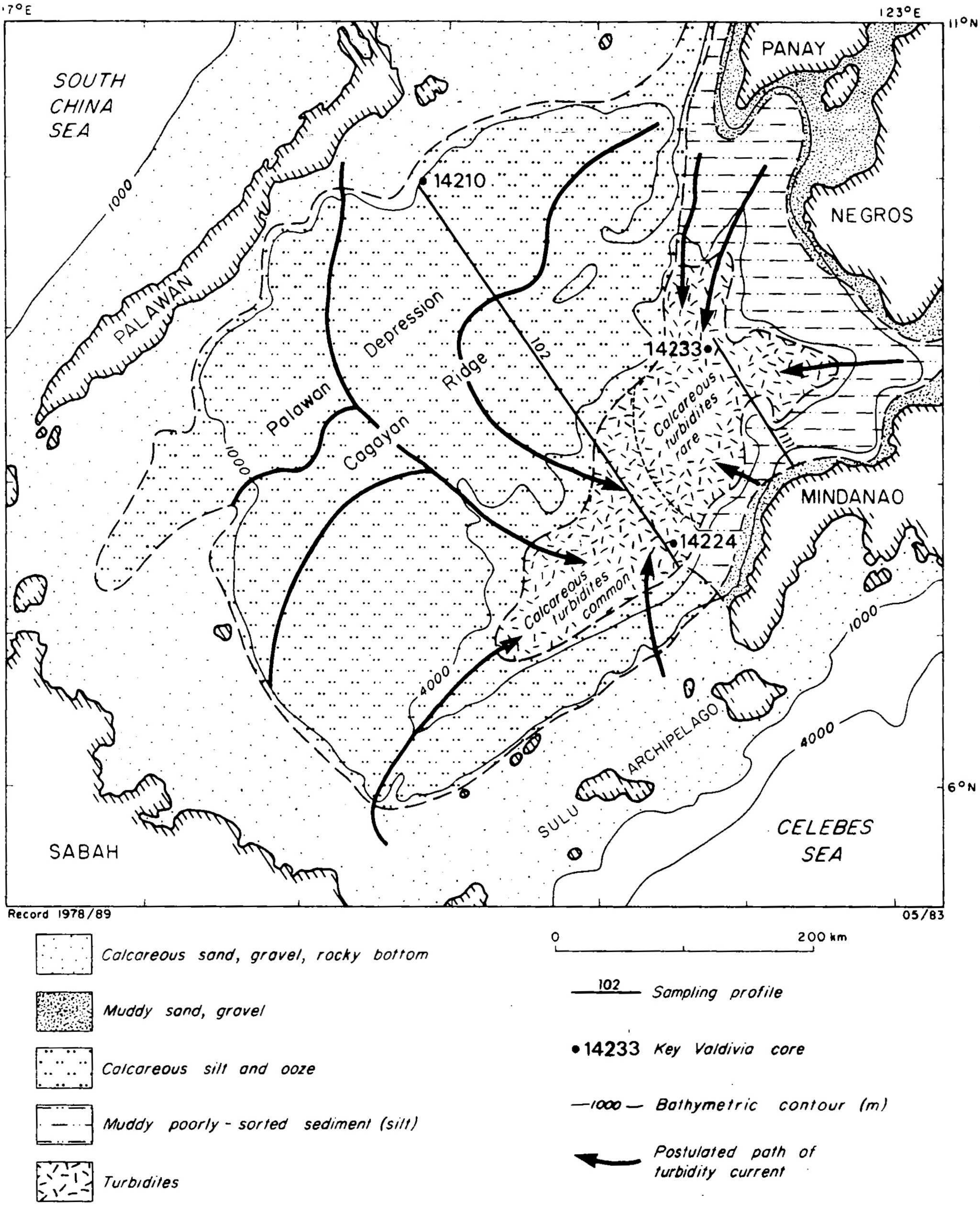


Fig. S2 Sulu Sea showing sediment flow pattern from the shallower northwestern Palawan Depression by the centrally-placed northeast-trending Cagayan Ridge. The sea's maximum sill depth is about 400 m, and the water column is layered, so the deep water, which is homogeneous, warm (10^oC) and oxygen deficient (< 1.6 ml/l O_2), is isolated from the open ocean. The bottom waters, although not anoxic, contain even less oxygen (as little as 0.55 ml/l).

Valdivia ran two sampling profiles from shelf to abyssal plain. The shelves off Palawan, Sabah and the Sulu Archipelago are generally broad and covered with calcareous sand and gravel, but in the east and southeast off Panay, Negros and Mindanao they are narrow and covered with muddy sediment. On the northwestern profile (102) shelf carbonates give way to bathyal oozes, and on the southeastern profile (111) muddy sands grade into varied silts dominated by volcanic and sedimentary debris. The smooth abyssal plain of the Sulu Sea Deep is 4800-5000 m deep, and north of it is another plain at 4000-4200 m. Turbidites characterise both plains. The aragonite and calcite compensation depths are at about 1400 m and 4500 m respectively.

The turbidite beds average 5-10 cm thick and Bouma's divisions, apart from A, are all recognizable. The southern turbidites (e.g. Core 14224) are of two types: calcareous and terrigenous. The calcareous turbidites, characterised by shell debris, were derived from the upper slopes flanking the broad shelves. The terrigenous turbidites, characterised by sedimentary and volcanic rock fragments, were apparently derived from the southern slopes. The eastern turbidites (e.g. Core 14233) are finer grained, characterised by sedimentary rock fragments, and came from the narrow muddy shelves of the east and southeast. Benthic foraminiferal assemblages confirm that the southern turbidites cannot have come from the muddy shelves.

Organic carbon contents are highest between 500 and 1200 m (greater than 2% in the southeast), lowest in the bathyal oozes of the northwest (as little as 0.2%), and in between in the Sulu Sea Deep (about 1%). Sediment colours appear to be related to organic carbon contents: olive tones above 1200 m and below 4500 m, and brown tones between. In the top 40 cm of sediment reducing conditions prevail on the slopes (denitrification zone), and more strongly reducing conditions prevail in the deep basins (sulphate reduction zone).

The sediments are characterised by living shelly faunas and intense bioturbation above 150 m, and by intense bioturbation and absence of a shelly fauna down to 3000 m. Bioturbation decreases below 3000 m, and in the Sulu Sea Deep is confined to a few Zoophycus and Chondrites burrows. The faunal changes are apparently related to bottom water oxygen concentrations.

Geotechnical results show a complex relationship between consolidation and overburden depth, and more advanced consolidation in turbidites than bioturbated Globigerina oozes. Interstitial water gradients indicate average sedimentation rates of about 10 cm/1000 years in turbidites, and less than half as much in oozes.

SCOTT PLATEAU AND JAVA TRENCH SAMPLING

In 1977 the R.V. Valdivia carried out a survey between Scott Plateau and the Java Trench during which 31 bottom samples were obtained in water depths ranging from 2000 m to 5800 m. N.F. Exon spent September 1977 at the Bundesanstalt fuer Geowissenschaften und Rohstoffe, Hannover, examining the material, and several months in 1978 helping to prepare a paper on the general results and editing papers on a large polygenetic manganese nodule, foraminifera, and coccoliths - all to appear in the December issue of the BMR Journal. Some time was also spent preparing a report (Record 1978/50) on details of sedimentology and palaeontology.

The Scott Plateau trends north-northeast and is bounded to the west by the Argo Abyssal Plain and to the north by the Roti Basin (Fig. S3). The plateau is a foundered continental block, and lies at an average depth of 2000-3000 m. The western margin probably formed during late Jurassic breakup, and ancient rocks are overlain by variable thicknesses of Mesozoic and Cainozoic sediments. Canyons cut the western margin, and some of these appear to be fault-boun-ded. The Argo Abyssal Plain slopes gently southward with water depths ranging from 5000 m near the Java Trench to 5730 m in the south. Oceanic basement is overlain by about 400 m of Late Jurassic and Cretaceous sediments that are in turn unconformably overlain by 200 m of layered Tertiary sediment.

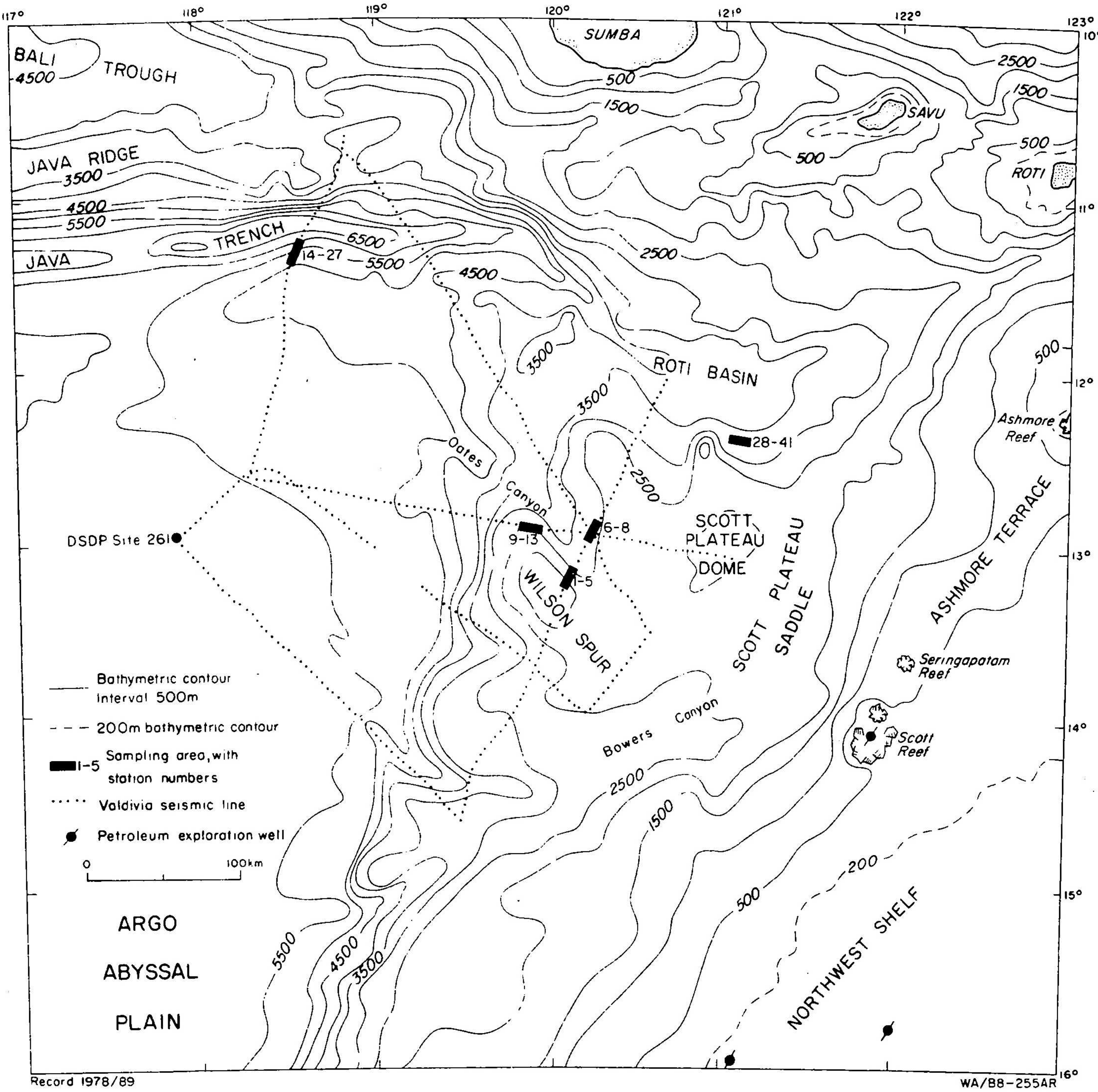


Fig S3 Sampling sites, Scott Plateau and Java Trench

Bottom samples taken by "Valdivia" from the outer Scott Plateau have provided new information about seismic sequences which were identified during the Scott Plateau interpretation program (see Geophysical Branch Summary of Activities). They show that Callovian breakup was preceded by a period of basic volcanism and shallow marine sedimentation, that restricted shallow marine conditions followed in the late Jurassic, and that bathyal carbonate sedimentation prevailed by the late Cretaceous (Campanian). The main results follow:

Amygdaloidal basalt, volcanic breccia and tuff, and very minor oolitic limestone and oolitic ironstone were dredged from just below the breakup unconformity on the outer plateau. This suggests that volcanics were interbedded with shallow marine sediments just before this part of Gondwanaland broke up in the late Jurassic.

Late Jurassic siltstones and some sandstones containing a variety of macrofossils were dredged from immediately above the breakup unconformity on the outer plateau. Their characteristics suggest that they were laid down in restricted shallow marine conditions, as were their correlates in the eastern Browse Basin.

Late Cretaceous marl, cored on the outer plateau, is rich in planktonic foraminifera and nannoplankton and was laid down in bathyal depths.

Latest Pleistocene and Holocene cores from the northern plateau are deep-water marls rich in typical tropical planktonic foraminifera and coccoliths. Sedimentation rates are 5-6 cm/1000 years. Very fine ash in these cores was carried more than 500 km from eastern Indonesia by tropospheric winds.

The Pleistocene-Holocene boundary was also penetrated on the southern slope of the Java Trench, where carbonate solution is prevalent and the sediments are siliceous oozes. Nannofossils are only preserved below a few decimeters in the shallower water cores, and these have an early or middle Pleistocene age. The calcite compensation depth lay between 5420 and 5720 m in the Pleistocene, and is now at about 4900 m. Sedimentation rates are much slower than those on the Scott Plateau. These cores contain several layers of volcanic ash.

Manganese oxide crusts are widespread on the northern Scott Plateau, and nodules were recovered in one dredge haul. Their contents of the valuable metals, nickel (0.38%), copper (0.05%), and cobalt (0.33%), were too low to give the discovery any commercial significance.

GREAT BARRIER REEF STUDIES

by

P.J. Davies

<u>DEVELOPMENT OF ROTARY DRILL</u> (P.J. Davies, D. Stewart, G. Thom, E. McIntosh and A. Koras)

A submersible rotary drill for use on the Great Barrier Reef was designed and built by BMR at a cost, excluding in-house labour, of $6000. The drill has a potential penetation capability of 60 to 100 m.

The essential components of the rock drill are an aluminium tripod and a rotary drill head. The tripod legs are 4.0 m long giving 3 m of head clearance above ground. The hydraulically powered rotary drill head is designed for an infinitely variable control of drilling speed in forward and reverse rotation (0-600 r.p.m.). It is guided in the vertical position by two aluminium rods and connected by umbilical hoses to the power unit. The latter consists of a 25 B.H.P. Onan petrol engine driving a variable displacement hydraulic pump. The hydraulic hoses are double-steel-braided and connected to drill head and hydraulic motors with snap hydraulic connectors. Water cooling of the hydraulic fluid and drill circulation are achieved with an 8 B.H.P. Briggs and Stratten petrol engine driving a Myers heavy duty pump delivering 10 gals/min at 500 p.s.i.

During drilling, pull down and pull up are achieved with a 3-ton Tirfor winch mounted on one leg of the tripod.

<u>DRILLING IN SOUTHERN GREAT BARRIER REEF</u> (P.J. Davies, J.F. Marshall, G. Craig, University of Edingburgh; D. Searle, D. Holdway, Geological Survey, Queensland; assistant D. Foulstone)

Between 22nd March and 19 May, 1978, field studies were made in the area of the Capricorn/Bunker Reefs in the southern Great Barrier Reef. Field operations consisted of rock and sediment coring, studies of surface morphology, and shallow seismic reflection profiling. The MV Sea Hunt, out of Gladstone, was chartered for the survey.

The drilling program consumed most time and effort during the field operations. The major objectives were to drill through the Holocene reef into the pre-Holocene substrate, and to sample in three dimensions the sediments in the lagoons and sand flats. Data generated will help solve: what is the relief of the pre-Holocene surface and its age? is the seismic refraction method reliable in tracing the Holocene/pre-Holocene junction? what are the Holocene stratigraphy and reef growth rates?, and what is the three dimensional variation of lagoonal sediment facies?

Seven drill holes were drilled on the windward and leeward sides of three reefs. Estimated recovery varied from 13 to 95%, and the depth drilled ranged from 5.8 to 18.2 m. Preliminary examination of the cores indicates major differences in faunal and sedimentary associations between windward and leeward reef margins.

SEISMIC REFRACTION STUDIES (P.J. Davies, J.F. Marshall; N. Harvey, James Cook University, Townsville)

In the Capricorn and Bunker Reefs of the Great Barrier Reef, 124 seismic profiles have been completed on six reefs and a marked seismic discontinuity detected at depths ranging from 8 to 23 m. A traverse close to the site of the Heron Island borehode shows that the seismic discontinuity is coincident with a marked solution unconformity recognized in the borehole. C^{14} dating of samples from this borehole and of samples below the unconformity at One Tree Reef (Table S1) prove conclusively that the seismic disconformity represents the Holocene/Pre-Holocene junction. At Heron Island it can be stated more conclusively that it represents the Holocene/Pleistocene boundary, a conclusion which most probably also applies elsewhere.

TABLE S1. Results of C^{14} dating of samples from Heron and One Tree Reefs

Sample No.	Site	Depth (m)	Mineralogy	Age (yr B.P.)
77631565 (NSW 262)	Heron Island borehole	15.3-18.3	Arag./HMC	>30,000
77631566 (NSW 263)	Heron Island borehole	18.3-21.0	LMC	>30,000
76631360 (SUA 744)	One Tree Reef windward side	19.8	LMC	28,000
77632028 (NSW 264)	One Tree Reef southern side	22.0	Aragonite	> 30,000
77632030 (NSW 265)	One Tree Reef southern side	22.0	Aragonite	> 30,000
77632034 (NSW 266)	One Tree Reef southern side	22.0	Aragonite	> 30,000

Sample numbers in parenthesis refer to radiocarbon laboratory number (NSW = University of New South Wales Radiocarbon Dating Laboratory; SUA = Sydney University Radiocarbon Laboratory)
HMC = high-Mg calcite; LMC = low-Mg calcite

Below the reefs of the Capricorn and Bunker Groups, the pre-Holocene surface forms a central depression with a raised rim broken at intervals. Where the substrate beneath the central area is deep, the modern reefs exhibit lagoons; where shallow, the lagoon has been totally or partially infilled. Substrate therefore has a dominant influence on the growth of modern reefs.

The variations in the thickness of Holocene growth on individual reefs, together with the close relationship of morphology to substrate control, suggest that the reefs of the Capricorn and Bunker Groups have not grown according to schemes of reef development described in the past. The classification of reefs as platform reefs, lagoonal platform reefs, closed ring and ingrown closed ring reefs is not borne out by our geophysical evidence. All the reefs are platform reefs, because they are underlain at shallow, but varying depths by pre-Holocene platforms. Variations in the morphology of the modern reefs can be attributed to variations in the shape of the platforms, while the depth of the platforms ultimately determines how closely the modern reef resembles its original shape. Reefs growing off shallow platforms will have reached a stabilised sea level earlier than reefs growing off deeper platforms, and will have undergone greater surface modification.

Models of reef growth for the Capricorn and Bunker Groups involving a genetically related series of reef types varying latitudinally from south to north is totally unsupported by the geophysical evidence. Wreck and Fairfax Reefs are the most similar in size, shape and depth to the pre-Holocene surface, but occur at opposite ends of the reef chain. Additionally, we suggest that the only real difference between One Tree and Lady Musgrave Reefs is that the pre-Holocene substrata beneath the lagoon at Lady Musgrave did not possess as many prominences for promoting lagoonal patch reef development.

BLUE HOLES OF THE POMPEY REEFS

In October 1977, P.J. Davies joined staff and students of James Cook University in an investigation of two Blue Holes in the Pompey Reefs, on the shelf edge east of Mackay. Blue holes are rare deep holes on reefs, usually in lagoons of shallow depth. These were were studied at Cockatoo Reef ($20^{o}45'$S, $151^{o}02'$E) and Molar Reef ($20^{o}38'$S, $150^{o}48'$E). Seismic refraction, coring, echo profiling and scuba exploration were carried out.

The Cockatoo Blue Hole is situated in a central position within the lagoon, and is some 40 m deep. It is oval in shape, (240 m x 205 m) and edged with a rim of living coral. The lagoon depth is 5 to 10 m. The inner slopes are very steep (60 - 70^{o}) down to -25 m, and comprised largely of living coral, below which a 30 - 45^{o} scree slopes to a flat floor at 40 m. Seismic refraction studies across the living coral rim show the Holocene/Pre-Holocene junction at a depth of 9 to 11 m, some 5 - 9 m higher than this surface below the lagoon.

The Molar Blue Hole is similarly situated in a shallow lagoon. It also has a living coral rim, is larger (295 m x 280 m) than the Cockatoo Blue Hole, but has a maximum depth of only 29 m. The inner slopes are generally not as steep as at Cockatoo Reef. Seismic refraction studies show the Holocene/Pre-Holocene boundary at shallow depths (~ 8.5 m) beneath the living rim.

The significance of the Blue Holes is that they represent karst erosion features. Both are probably relict collapse dolines which formed during successive Pleistocene low sea level periods. Such evidence of substrate affecting reef growth must lead to a reassessment of the principal factors operative in coral reef growth.

CONTINENTAL SHELF OF EASTERN BASS STRAIT AND EASTERN TASMANIA

by

P.J. Davies

This study forms part of a project which has as its main objective an understanding of the geology and mineral resources of the Australian continental shelf.

Quartz and carbonate sands dominate the surface sediments of the Bass Strait and east Tasmania continental shelves. Admixed gravel occurs especially in eastern Bass Strait and to the west and northwest of Flinders Island. The gravel is composed of molluscan/bryozoan debris, except in shallow water off southern Tasmania where rock fragments dominate. Silty sands occur as lenses on the east Tasmania shelf and in Bass Strait. The outer shelf and upper slopes are generally characterised by poorly sorted sediments. Well sorted sediments occur in shallow water. Sorting characteristics are mainly determined by the percentages of gravel and mud. Four principal sedimentary facies have been identified on this shelf:

1. Quartz sand facies on the inner Gippsland and east Tasmania shelf;
2. Comminuted foram/bryozoan/fine quartz facies in the mid-shelf off eastern Tasmania and Gippsland;
3. Coarse molluscan/bryozoan facies over much of eastern Bass Strait and the outer shelf off eastern and southern Tasmania; and
4. Mixed bryozoan/quartz facies on the outer shelf in eastern Bass Strait.

The quartz sand facies forms the nearshore modern sediment wedge, while all other facies are probably mixed, containing modern and relict components.

Sediments were analysed for variations in both main group and transition metals and non-metals. Concentrations of calcium carbonate generally increase away from the coastline, values of greater than 80% dominating the outer shelf. Strontium values follow calcium carbonate. Magnesium values are low in the close inshore sands ($< 0.5\%$) but much higher (1.5%) in the carbonate-rich areas, this reflecting carbonate mineralogy. Conversely, titanium is appreciably higher in the close inshore sands, values greater than 2000 ppm occurring to the north of Great Oyster Bay. Arsenic values are generally low, except to the south and southwest of Storm Bay where values greater than 50 ppm occur in patches. The Bass Strait and Tasmanian sediments are manganese-deficient. Values in excess of 100 ppm occur only to the southwest of Storm Bay and west of Flinders Island. General manganese deficiency in these sediments follows the pattern for most shelf sediments of eastern Australia.

OFFSHORE HEAVY-MINERAL SANDS

by

H.A. Jones

A review of the prospects for offshore accumulations of heavy-mineral sands on the New South Wales continental shelf, based on a paper given at the 25th IGC by Jones and Davies, was prepared for an outside publication. Areas of adequate sediment thickness have been outlined from seismic data and possible submerged strandlines identified from detailed study of sea-floor morphology. The near-shore sediment wedge can commonly be divided into an upper and lower sequence based on differing acoustic characteristics or on an obvious depositional hiatus, and there is some evidence of enrichment with heavy minerals at the base of the upper sequence. From a combination of these factors the most promising areas for further exploration appear to be between Evans Head and Cudgen, north of Nambucca, north of Port Macquarie, between Forster and Port Stephens, and east of Newcastle.

About 70 heavy-mineral fractions separated from surface sediment samples from Bass Strait and the Tasmanian shelf are being examined by J.B. Colwell. Five distinct heavy-mineral suites have been identified and a study of provenance implications is in progress.

OVERSEA VISIT

P.J. Davies attended the 10th International Congress of Sedimentology in Jerusalem from the 8 - 26 July, participated in field excursions to the Sinai and the Gulf of Elat and visited Government and University Institutions in Israel.

Prior to the Jerusalem Meeting, he visited the Smithsonian Institution in Washington, where he examined cores from reefs in the Atlantic and Central Pacific, and universities in Britain, where discussions largely centred on equipment for sampling suspension load in wave dominated environments. These visits proved invaluable and will have a major bearing on future field activities in the Great Barrier Reef.

PALAEONTOLOGICAL STUDIES

(Reported by individual scientists, alphabetically)

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

Data entry into the palaeontological retrieval system continued throughout the year, principally for the Commonwealth Palaeontological Collection (CPC) and the ESCAP Fossil Reference Collection. The program is working successfully; a catalogue has been prepared for additions to the ESCAP Collection, and has been issued as Supplement 2. Curation of the Bureau's foraminiferal collection continued.

During August, Carboniferous and Permian type and reference sections in the Carnarvon Basin were sampded. This material will be incorporated in the collection as a faunal and lithological reference collection.

A paper describing the planktonic fauna from a Campanian sample collected by the R/V "Valdivia" on the Scott Plateau is almost completed. This paper is to be included as an appendix in a Bulletin on the area, now in preparation.

Palaeontological work for the Papua New Guinea Geological Survey and the Irian Jaya Project continued as required. Assistance was also given to Dr C. Klootwyk, ANU, in connection with a palaeomagnetic study in India and Pakistan.

The Crespin Commemorative Volume, compiled jointly with Dr Viera Scheibnerova, was issued as BMR Bulletin 192 in April. This volume, comprising mainly palaeontological papers, is a tribute to Dr Irene Crespin in recognition of her contribution to Australian geology.

D. BURGER (assistant L. Kraciuk)

Carpentaria Basin. Palynological study of Jurassic and Cretaceous sediments in the subsurface of the Carpentaria Basin included stratigraphic and taxonomic work on dinoflagellate cysts and acritarchs, and stratigraphic work on spores and pollen grains (both gymnosperms and angiosperms), most of which have been described elsewhere. The main objects of this study are:

1. to examine the extent of Jurassic sedimentation (Helby Beds) in the northern part of the basin, and correlate the associated palynological sequence with that of the Eromanga and Surat Basins.
2. to examine the dinoflagellate contents of the lowest Cretaceous (Neocomian) sedimentary rocks, including the Gilbert River Formation, Helby Beds, and basal Rolling Downs Group, which amount to a virtually complete Neocomian marine sequence, unique for eastern Australia. The possibilities for correlation with Neocomian sequences in Europe and North America are explored in a separate forthcoming paper.
3. to examine the Albian angiosperm pollen record, in the context of information from the Albian from the Eromanga (SA), Surat (Qld), and Otway Basins (SA, Vic.). It is hoped that the Carpentaria Basin record will help in solving apparent discrepancies existing between the Surat Basin and Eromanga Basin sequences.

Continuing projects include curating of the CPC and palynological study collections, data storage processing (computer program), extending the edge punch-card collection of fossil and dinoflagellate genera of the world, re-arranging in morphological order about 3600 cards of fossil spore and pollen genera of the world (Special Publ. Dept. Geol. Univ. Calgary), and a study of literature and laboratory methods connected with a pollen autofluorescence study.

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

Studies of Oligo-Miocene larger foraminiferids from Australia, and Oligocene to Holocene planktic foraminiferids from northwest Australia and Victoria, have continued.

Late in 1977, most of the important late early Miocene larger foraminiferid localities in Victoria were sampled. Very little work has been carried out so far, but results to data show that Cycloclypeus preferred warmer-water conditions than Lepidocyclina (Nephrolepidina), as is evidenced by their geographic distribution; Cycloclypeus becomes rarer southwards.

A paper based on biometric studies on larger foraminiferids from Australia is in press. This paper evaluates the biostratigraphic usefulness of biometric parameters for five genera of larger foraminiferids. Of these only two are of particular use: Cycloclypeus and Lepidocyclina (Nephrolepidina); of these Cycloclypeus provides the more accurate tool for correlation.

A paper dealing with larger foraminiferal biostratigraphy in Australia is in preparation. This details the eight associations already mentioned in an earlier paper (Palaeoecology of Oligo-Miocene larger Foraminiferida, Australia, Alcheringa, 1, 37-58). These associations are correlated with both the planktic zonal scheme of Blow (1969, 1970) and the Tertiary letter stages. Because the associations were environmentally controlled, they are of only limited usefulness for accurate biostratigraphic correlation.

J.M. DICKINS (assistants A. Haupt and R.W. Brown)

Continuation of Permian studies is extending the knowledge of the system both in Australia and in other parts of the world. Description of an early Permian marine invertebrate fauna from Warwick, Queensland, has been completed. This is aimed at allowing a more precise time correlation of eastern Australian sequences. The fauna also provide information indicating that the range of east Australian species varies according to water temperature.

A paper on world late Palaeozoic climate is being prepared for the 9th Congress on Carboniferous Stratigraphy and Geology to be held in USA in

May 1979; J.M. Dickins is the convenor of the symposium on Late Palaeozoic climate at this conference. Field work carried out during the year in the Carnarvon Basin, Western Australia, has indicated that five glacial stages and four interglacials can be recognised (late Carboniferous - early Permian). Fossil collections were made in this basin to allow a more precise time-correlation of Australian Permian rocks. The fieldwork has also contributed to understanding the tectonic and sedimentological development of the basin during the Permian.

Work in collaboration with the Department of Geology, University of Newcastle, has been carried out in the northern part of the Sydney Basin: a northwest to southeast trough was apparently present in the early Permian, and the Lochinvar Dome (the present major structure in the area) began to develop only at about mid-Permian time. A paper has been prepared describing a terrestrial moraine in the early Permian Lochinvar Formation - terrestrial moraine has not been hitherto recognised in this part of the sequence. Fossil collections have been made to improve the understanding of the sequence.

A Bulletin on the Tertiary ground-birds of Australia by Pat V. Rich was edited and marked up, and tendering has now been completed for publication by the Australian Government Publishing Service. The material described comes mainly from BMR collections.

Organisation of the Palaeontology areas and the fossil collections has been a continuous responsibility, as have activities in support of the Commission on Stratigraphy of the International Union of Geological Sciences (mainly associated with Gondwana Subcommission as Chairman and the Permian Subcommission as a member).

E.C. DRUCE (assistants K. Heighway, A.T. Wilson)

Research continued on the conodont faunas of the Georgina Basin in order to provide an Ordovician time frame for detailed lithological and geochemical studies (see Project Branch Report). A key conodont in North American Tremadocian sequences was recovered from the Ninmaroo Formation in the Burke River Structural Belt, Queensland, and in the Tobermory area, Northern Territory. Its occurrence with Cordylodus proarvus enables a firmer correlation to be made of the Lower Tremadocian part of the Georgina Sequence with north American sections.

A study of conodonts, trace fossils and the petrology of the Kelly Creek Formation is presently being undertaken. The unit, which is dominantly a sandstone with interbeds of gypsum, straddles the Tremadocian-Arenigian boundary.

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

Carboniferous and Devonian ostracods, Devonian eridostracans and thelodont scales, and Cambrian bradoriids have been studied in order to determine their age and ecological significance as aids for correlation.

The taxonomic and biostratigraphic revision of a manuscript on 'The Early Carboniferous Ostracoda of the Bonaparte Gulf Basin' was continued, and the preparation of a joint paper (with Dr I.G. Sohn - U.S. Geological Survey, Washington, D.C.) entitled 'Carboniferous ostracodes - a biostratigraphic evaluation' was started for the symposium on 'Zonation of the Carboniferous by microfossils', to be held at the 9th International Congress of Carboniferous Stratigraphy and Geology, May 1979.

Preliminary work on Early Carboniferous ostracods from NSW showed some interesting differences in the composition of faunas from the Brushy Hill Limestone (middle Tournaisian), and the Caroda Formation (Visean). The differences are not only due to differences in age, but also reflect differences in depositional environments.

Further collections were made from the Upper Devonian and Lower Carboniferous sequences of Western Australia. In the Bonaparte Gulf Basin, the type section of the Buttons Beds (Famennian) was recollected, and many subsurface samples covering the Devonian/Carboniferous interval were selected from core collections, through the courtesy of Australian Aquitaine Minerals Pty Co. In the Canning Basin, sampdes were recollected from the Fairfield Group. The WA material will be studied in order to refine the biostratigraphic control necessary for subsurface correlation, and to check the validity of previous interpretations.

The studies of Devonian thelodont scales and eridostracans, and Cambrian bradoriids, are reported under the Georgina Basin Project.

M.D. MUIR (assistants K.J. Armstrong, A. Haupt, P.W. Davis)

The major emphasis for this year's work has been on expanding the number of known Precambrian microfossil assemblages, particularly in relation to the McArthur Basin Project. New microbiotas, currently under study, comprise assemblages from the Wollogorang Formation (Tawallah Group), the Emmerugga Dolomite, Balbirini Dolomite and Kookaburra Creek Formation (McArthur Group), and the Corcoran Formation (Roper Group). Continuing work is being carried out on the Mallapunyah Formation, Amelia Dolomite (McArthur Group), and the Urquhart Shale (Mount Isa Group). The results of these studies will assist the construction of a detailed biostratigraphic framework for the Carpentarian in the McArthur Basin, as well as producing environmental evidence.

A new Archaean microfossil assemblage was described from the Warrawoona Group, at the North Pole barite mine, near Marble Bar, Western Australia. The fossil come from sediments dated at 3.5×10^{9} years old.

In addition, continuing work on the organic walled spheroids from the Hamersley Group has involved the use of statistical methods.

Microfossil assemblages from the Babbagoola Beds of the Officer Basin are being studied with M.J. Jackson. Preliminary results indicate that these assemblages are Lower Cambrian. A chert boulder from Permian tillite contains a microfossil assemblage of a type comparable to those in the Bangemall Group.

Miscellaneous activities include identification of Mesozoic fossil plant stems and wood from the Hooray Sandstone of the Eromanga Basin, and a study of a sandstone from the Canberra region which contains fossil megaspores.

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

The study of Silurian conodonts from the ACT and surrounding New South Wales continued. Several samples with conodont faunas of late Silurian age were examined for the Araluen field project.

Study of Late Devonian conodont faunas from the Oscar and Napier Ranges, Canning Basin, WA, continues with most of the material now identified.

Several multielement taxa have been recognized and others will probably be isolated when the data are examined statistically.

Field work was undertaken in the Bonaparte Gulf, Canning and Carnarvon Basins, WA. The object of the collecting was to fill gaps in biostratigraphic collections from these basins so that summary studies of Devonian and early Carboniferous conodont faunas can be completed.

A meeting of the Pander Society, held in the USA., was attended. Papers presented on paleoenvironmental aspects of conodonts, especially of Devonian and Carboniferous age should be of direct benefit to the study of the WA sedimentary basins. A technical session on the use of conodonts as a tool in the interpretation of the temperature to which sedimentary rocks have been subjected was informative. This line of study may have some potential in several areas in Australia where petroleum exploration is being carried out in Palaeozoic rocks.

A.A. OPIK (assistant A. Haupt)

Opik continued the systematic study of trilobites in association with the Palaeontological Group. A major study of Cambrian agnostid trilobites is in press (Bulletin 172) and one on the Dolichometopidae is well advanced.

M. PLANE (assistant R.W. Brown)

The study of Cainozoic mammalian fossils continued with the aims of establishing their age ranges and environmental implications as an aid to the correlation of non-marine Tertiary rocks.

Fossil faunas under study are from Bullock Creek and Kangaroo Well in the Northern Territory; Riversleigh, Queensland; and Lakes Palankarinna, Pitikanta and Kanunka in South Australia.

A combined party from BMR, South Australian Museum, National Museum of Victoria and the Queensland Museum, again worked the South Australian lake sites. The three principal sites worked were White Sands basin, Mammalon Hill and Neville's Nirana. The last is a new site which produced numerous bird bones, including a partial skull. The Mammalon Hill site is particularly significant having produced a whole mandible of the enigmatic Ektopodon, and a diprotodontid, previously unknown, and unlike anything known from the many other sites in the Miocene Etadunna Formation. Much material from these sites was shipped to Melbourne and Canberra for subsequent processing - weather conditions being such as to make field processing impossible. Further material was collected from newly found sites at Lakes Kununka and Pitikanta and this was also shipped to Melbourne for processing.

The laboratory processing of material from Kangaroo Well, Northern Territory and the South Australian lake sites continues. Acid preparation of the material from the Territory is proving successful and one small mammal jaw with a single tooth has been recovered; it is a new taxon. Several new animals, based on isolated teeth, have been recovered from the Lake Palankarinna concentrates.

A publication on the Miocene fossil platypus Obdurodon insignis from the Etadunna formation is in press.

The teaching scheme for Trainee Technical Officers continued into the early part of 1978 and 10 trainees were given a full course of instruction on palaeontological laboratory techniques.

SAMIR SHAFIK (assistants F. Hadzel and P.W. Davis)

Calcareous nannofossil biostratigraphic studies concerning the Australian marine Upper Cretaceous and Cainozoic sediments resulted in the publication of three papers; a further two are in press. Areas dealt with during 1977/78 are restricted to western Australia and include offshore areas. Upper Cretaceous as well as Tertiary sediments in the Perth Basin were analysed for their calcareous nannofossils. In addition, sediments representing the oldest known Upper Cretaceous containing calcareous microfossils in the Carnarvon Basin were studied. Calcareous nannofossil assemblages of the Oligocene-Miocene sequence of the Bonaparte Gulf Basin were recorded. From the offshore areas encompassing the Scott Plateau and Java Trench, Upper Cretaceous and Quaternary calcareous nannofossil assemblages were recovered, and the significance of these assemblages for carbonate sedimentation in these areas of the Eastern Indian Ocean was discussed.

The Upper Cretaceous-Tertiary sequence of the Perth Basin includes three rock units - the Gingin Chalk, Lancelin Beds and Kings Park Formation - known to contain calcareous microfossils. The Gingin Chalk and Kings Park Formation were studied and the results are published in BMR Journal 3(3) and in the BMR Bulletin 192 respectively. The main conclusions are discussed below.

Gingin Chalk Based on diversified calcareous nannofossil assemblages recovered from outcrops of the Gingin Chalk in the Gingin area, a new (Santonian) nannofossil zone was proposed; a necessary redefinition of two other (Coniacian and Campanian) zones was also included. This new zone, the *Lucianorhabdus maleformis* Zone could be recognised in the coeval Toolonga Calcilutite in the Carnarvon Basin. Correlation of the *L. maleformis* Zone with other zones which have been applied to sediments elsewhere (Europe, USA) ties the Gingin Chalk with other sequences, particularly the European Upper Cretaceous.

The nannofossil evidence indicates that the deposition of the Gingin Chalk was in an epicontinental sea with good access to the open ocean; provincialism which has been recorded among the ostracod faunas of the Gingin Chalk by other workers could not be detected among the nannofossil assemblages.

Kings Park Formation Two different nannofossil biostratigraphic units could be recognised in the Kings Park Formation in two different areas. The older unit - widely distributed underneath the city of Perth - includes nannofossil assemblages of late Paleocene and latest Paleocene to earliest Eocene ages, and thus conforms with the traditional age assignment of the formation; the type Kings Park Formation belongs to this unit. The younger biostratigraphic unit contains middle Eocene nannofossil assemblages, and is based on material from the Rottnest Island Bore. This unit has not been recorded before and is absent in the type area of the formation. Thus a biostratigraphic gap of a substantial duration separates the Kings Park Formation in its type area (Perth metropolitan area) and its occurrence in the Rottnest Island Bore.

Evidence suggesting that the Kings Park Formation was deposited during two separate sedimentation cycles includes the occurrence of reworked nannofossil taxa in the type section of the formation and in its beds in the Rottnest Island Bore.

The study concluded that some significant geohistorical events, probably regional, occurred between the deposition of the type Kings Park Formation and the deposition of the middle Eocene beds in the Rottnest Island Bore. The study, therefore, recommended that the middle Eocene Beds in the Rottnest Island Bore be given a separate lithostratigraphic status.

Carnarvon Basin The Gearle Siltstone is the oldest Upper Cretaceous formation in this basin known to contain calcareous microfossils. In some areas in the northern part of the basin, the Gearle Siltstone has been differentiated into two units which are known informally as the 'lower' and 'upper' Gearle Siltstone. Calcareous nannofossil biostratigraphies of these units and of the type Gearle Siltstone helped in proposing a stratigraphic nomenclatural revision.

The 'upper Gearle Siltstone' is recognised as a separate unit, distinct from the underlying 'lower Gearle Siltstone' or its lateral equivalent the undifferentiated Gearle Siltstone. A new name, the Beedagong Member, is proposed to replace the informal name of 'upper Gearle Siltstone', and the other informal name of 'lower Gearle Siltstone' is considered synonymous with the name Gearle Siltstone. The Beedagong Member is identified as belonging to the Toolonga Calcilutite, and accordingly the concept of the Toolonga Calcilutite is slightly enlarged to accommodate this member.

The Beedagong Member at the base of the Toolonga Calcilutite is assigned to the late Turonian-Coniacian *Eiffellithus eximins* and *Marthasterites furcatus* nannofossil Zones. The latter (younger) zone extends into the Toolonga Calcilutite beyond the upper limit of the Beedagong Member in some sections; the top part of the underlying Gearle Siltstone contains Albian (early Cretaceous) calcareous nannofossils.

A manuscript on these results has been submitted to the Royal Society of Western Australia.

Bonaparte Gulf Basin This basin contains a valuable reference section spanning the Oligocene-Miocene transition. The calcareous nannofossils of the section have been recorded, and their bearing on the recognition of the Oligocene-Miocene boundary in shelf deposits and deep oceanic sediments are discussed in BMR Journal 3(2).

Offshore areas of the NNW of Australia Results are contained in the BMR record 1978/150, and are summarised in a short paper (in press) BMR Journal 3(4).

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

J.H. Shergold participated in the Australia-USSR Science Exchange Agreement in January and February 1978, visiting Cambrian palaeontological research workers in the Geological Institute, USSR Academy of Sciences, Moscow; the Palaeontological Institute, USSR Academy of Sciences, Moscow; the Institute of Geology and Geophysics, Novosibirsk; the Institute of Geology, Kazakhstan Academy of Sciences, Alma-Ata; the All Union Geological Research Institute (VSEGEI) and the Institute for Geology of the Arctic in Leningrad. En route to Russia visits were made to the Universities of Delhi and Jammu in India; the Institute of Geological Sciences and British Museum, U.K.; the National Palaeontological Museum, Paris, and the Claude Bernard University, Lyon, France; the Palaeontological Institute, University of Wurzburg, Germany; the Geological Survey of Czechoslovakia and National Museum, Prague; the Palaeontological Museum, Humbolt University, Berlin, D.D.R.; and the Geological Survey of Poland, Warsaw, and University of Warsaw, Poland. Returning from Russia, visits were paid to the Geological Survey of Sweden, and Naturhistoriska Riksmuseet, Stockholm, University of Uppsala, and University of Lund, Sweden. At all these places Cambrian and early Ordovician trilobites from historical collections were examined and replicated for later reference.

Considerable time was spent in organising (in association with Dr P.J. Cook, of A.N.U.) an inaugural international field workshop and seminar for IGCP Project 156 (Phosphorites: Proterozoic/Cambrian of Australia and Asia). This meeting was attended by 58 scientists from 12 countries who examined Middle Cambrian phosphorite deposits in the Georgina Basin in mid-August during the field workshop, and then proceeded to Magnetic Island for a seminar on phosphorites. In connection with this IGCP Project, Shergold was invited in April by the East-West Resource Systems Institute, Honolulu, to participate in an international meeting to initiate an international phosphate resource data bank. The meeting was cosponsored by IGCP, EWRSI and the USGS.

In June, Shergold participated in a scientific exchange scheme which is operated by the Australian Academy of Science and Academia Sinica. With six others, visits were made to the Institute of Geology, Academia Sinica, Peking, the Academy of Geology of the State Bureau of Geology and Mineral Resources, Peking; and the Institute of Geology and Palaeontology, Nanking. Field visits were made to the Sinian System at Chi-Hsien in north China, and the Sinian and Cambrian of central Yunnan, including the phosphatic Lower Cambrian sequences of the Kunming area. Older Cambrian trilobite collections (Sun, 1924) were examined and replicated whilst in Nanking.

A paper describing the Upper Proterozoic and Lower Palaeozoic rocks of the Georgina Basin was given at the 3rd Australian Geological Convention in Townsville in late August.

A Bulletin describing 52 species of Late Cambrian trilobites from the type area of the Chatsworth Limestone, in the Burke River Structural Belt, western Queensland, was submitted for publication in November. A guidebook to the geology of the phosphate deposits of western Queensland was prepared for IGCP Project 156 excursion in July. Two Records, dealing with the petroleum prospects of the Georgina Basin, and the 1975-6 BMR stratigraphic drilling program in the Burke River area, were issued under joint authorship.

Other activities included the review of papers sent by outside journals for assessment; field work in the Georgina Basin (see Georgina Basin Project), and the gathering of suitable manuscripts for inclusion in a volume of Alcheringa dedicated to A.A. Opik.

Work proceeds on the palaeontological assessment of Georgina Basin boreholes; Idamean trilobites from the Burke River area; late Cambrian trilobites from northern Victoria Land, Antarctica; and early Ordovician trilobites of the Georgina Basin.

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

S.K. Skwarko continued with research into the Mesozoic fossil molluscs of Australia, Papua New Guinea, and Indonesia, the main emphasis during the year being the Jurassic Buchiidae of Papua New Guinea and Indonesia, and belemnites of Indonesia, the Triassic Bakevellidae of Papua New Guinea, and the Cretaceous Trigoniidae of Cape York Peninsula, Australia.

Skwarko gave a series of lectures on the Australian Mesozoic geology at the James Cook University of North Queensland; he also prepared for publication a manuscript on the Mesozoic Geology of Papua New Guinea.

Much time was spent in drawing up lists of laboratory and preparatory equipment, office furniture, and lists of books, monographs, and separates for the forthcoming Mesozoic Macrofossils Study Group at the Geological Survey of Indonesia in Bandung.

Routine duties involved Skwarko in the continuing revision of the Australian Cretaceous ammonites and bivalves, and the maintenance of the computerised retrieval system of palaeontological bibliographic references on Mesozoic and Ordovician faunas.

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

D.L. Strusz is engaged in a statigraphic and palaeontological study of the Palaeozoic rocks of the ACT and surrounding districts, as a contribution to the understanding of the tectonic and metallogenic evolution of the Lachlan Fold Belt.

The stratigraphic aspects of this study at present involve supervision of 1:100 000 mapping by R.S. Abell (Canberra Sheet), and M. Owen and D. Wyborn (Araluen Sheet). There is also significant cooperation with the Engineering Geology Group.

On the palaeontological side, the greatest need - and hence the focus of attention - is for biostratigraphic information for Silurian shelly fossils, many of whose Australian representatives are either still undescribed, or have not been revised in the light of modern systematics. This is thus also a contribution to Project Ecostratigraphy, a Category A project of the IGCP. The first study, just complete, is on the trilobite family Encrinuridae, a widespread group which was much in need of revision. Within Australia, the stratigraphic results have been disappointing in terms of possible zonation, but future work will have a much firmer systematic base on which to proceed. A broader and probably more rewarding study, of the brachiopod faunas, has started with a large collection of well preserved material from a Wenlockian locality just west of Canberra (when complete, this will be the first fauna of that age in Australia for which the important members will be well known).

Further activities have been:

1) Curatorial work on the Canberra collections.
2) Australian correspondent for the newsletter 'Fossil Cnidaria' of the International Research Group on Fossil Corals and Coral Reefs.
3) Member of the Editorial Board of the Geological Society of Australia.

E.M. TRUSWELL (assistant L. Kraciuk)

Research during 1978 was associated both with the Palaeozoic and Cainozoic. For the Palaeozoic, work continued with the palynological study of the Joe Joe Group in the Galilee Basin, Queensland. A preliminary survey of the palynological sequence in GSQ Springrove No. 13 borehole was completed; some 27 form-species of spores and pollen were isolated. A formal description of these was begun, supported by optical microscope and scanning electron photography. Work was extended to the GSQ boreholes Jericho Nos. 1 and 2, and taxonomic description of palynological elements in the Joe-Joe section in these boreholes is currently underway.

For the Cainozoic, four articles dealing with aspects of the evolution of the Cainozoic environment in Australia were published or sent to press. A review article dealing with climatic evolution and vegetation history was published in Palaeogeography, Palaeoclimatology, Palaeogeography (24, 169-208) in mid-1978. A summary of the article was subsequently prepared for the forthcoming book 'Ecological Biogeography in Australia' at the request of A. Keast, its editor. A second article 'Late Cainozoic environments in Australia', which was authored jointly with R.W. Galloway, of CSIRO Land Use Research, is already in press in the same volume, and proofs were corrected during 1978.

In October 1978, a conference entitled 'Fire and the Australian biota' was held at the Academy of Science in Canberra, organised by the Australian committee of SCOPE, the Scientific Committee on Problems of the Environment. A paper entitled 'Pre-Quaternary Fire in Australia' was presented at the conference, in order to provide background for studies of modern fire ecology. The proceedings of the conference are to be published by the Academy.

JOYCE GILBERT-TOMLINSON (assistant M. Doyle)

The study of Permian and Mesozoic ichnolites from the Western Australian sedimentary basins (especially the Canning Basin) is drawing to its close. The superb preservation of the local material permits a better understanding of the morphology of a number of established ichnogenera and, for the first time, the compilation of differential diagnoses for superficially similar forms.

A brief note on trace fossils from Jurassic sediments dredged from the Scott Plateau, Java Trench, was written jointly with N.F. Exon (Record 1978/50). Other activities included lecturing to local societies and arranging museum exhibits.

M.R. WALTER (assistants A. Haupt, P.W. Davis)

A study of the palaeontology of the iron formations of the Early Proterozoic Frere Formation of Western Australia and the Gunflint Iron Formation of Canada, jointly with Professor S.M. Awramik of the University of California, was continued. A manuscript on the fossil cyanophyte Frutexites has been submitted for publication. Preparation of this manuscript was completed during a brief visit to Santa Barbara during June.

Columnar branching stromatolites from the Pioneer, Boord and Julie Formations in the Amadeus Basin, and the "Yackah Beds" in the Georgina Basin, have been described in a joint study with Dr I.N. Krylov, Geological Institute, Academy of Science, Moscow. Dr Krylov visited Australia for 9 weeks on a study tour organised by Walter under the auspices of the Australia-USSR Agreement on Scientific and Technical Co-operation.

Study of microfossils from black cherts from the Madley Diapir, Officer Basin, suggested that the sediments in the core of the diapir were derived from a correlative of the Bitter Springs Formation of the Amadeus Basin. A rich assemblage of well preserved microfossils was found. Precambrian stromatolites and carbonate sediments in the Mount Isa region were examined, and a report was prepared on preliminary environmental interpretations.

A week was spent in Los Angeles at the University of California planning the activities of the Precambrian Paleobiology Research Group. This group of 7 specialists, including Walter, will commence its research next May and continue for 15 months studying various aspects of Archaean and Early Proterozoic palaeontology, sedimentology and geochemistry.

A tour of Holocene carbonate environments in Australia was organised for a group of 8 geologists and microbiologists from the McArthur Basin, Georgina Basin and Spencer Gulf projects. The group visited the Coorong Lagoon area, Marion Lake area, Hutt Lagoon, Shark Bay and Lake MacLeod.

Three weeks was spent on a study tour of China, in the company of 6 other Australian geologists and biologists, in an exchange between the Australian Academy of Science and Academia Sinica. The main purposes of the tour were to examine Proterozoic and lower Cambrian sedimentary sequences, study the fossils known from these sequences, and to strengthen contacts with Chinese scientists in these fields. Several days were spent in the field examining sequences in Yunnan and east of Peking. Walter gave 4 lectures on Australian Precambrian fossils, stromatolite biostratigraphy and iron-formations. Many similarities were observed between Chinese and Australian Precambrian stromatolites, and further comparative studies would be rewarding. The Chinese are well advanced in the study of Precambrian and Cambrian acritarchs and their use in biostratigraphy and we have much to learn from them in that field. A collection of Chinese literature on stromatolites, and specimens, is being returned to Australia.

Planning for the International Symposium on Environmental Biogeochemistry, to be held in Canberra in August 1979, was continued. Continuing contributions were made to the following IGCP projects, the first as a joint convenor and the others as a full voting members: Early Organic Evolution and Mineral and Energy Resources, Upper Precambrian Correlations, Precambrian-Cambrian Boundary.

Two doctoral students are being supervised: one at ANU studying the sedimentology of the Proterozoic sediments in the Mount Isa region, and one at the University of Western Australia studying the sedimentology, palaeogeography and palaeontology of an Archaean sequence in the Pilbara Block. Several days were spent in the Pilbara examining Archaean sedimentary rocks.

Walter's activities within the Georgina Basin are described in the Project Branch report.

G.C. YOUNG (assistants A. Haupt, R.W. Brown)

During the year the systematic study of Devonian fish material was continued, and some new specimens were added to the collections. The object of this research is to make known the abundant fish faunas which occur in Lower and Middle Palaeozoic rocks throughout Australia, and in Victoria Land, Antarctica, and thereby to provide new information on the structure and evolutionary history of early vertebrates, and basic taxonomic data for biostratigraphic and palaeogeographic studies. In accordance with the 1978 program, effort was concentrated on the study of Lower Middle Devonian material from the Taemas/Wee Jasper region of NSW and Middle-Upper Devonian material from Victoria Land, Antarctica. Two major works on the Taemas/Wee Jasper fauna were submitted for publication during the year; in one, comprehensive details of brain-case structure in the euarthrodiran placoderm Buchanosteus are described for the first time, a new analysis of euarthrodiran evolution is presented, and revised diagnoses for the order and all subordinal categories down to species are proposed. The second work describes a new genus and species of placoderm fish in which the brain-case was more completely ossified than in any previously known form, permitting a reinterpretation of cranial nerves and vessels for the group as a whole. A new scheme of evolutionary relationships within the subclass is put forward. A shorter paper which appeared in the journal Alcheringa describes a new species of petalichthyid placoderm from this fauna.

The study of the Antarctic collection was continued; supporting work was also carried out in the preliminary study and description of Middle-Late Devonian fish material collected by the Geology Department, ANU, from the Eden/Pambula region on the NSW south coast. In this fauna a new antiarch previously known only from Antarctica has been identified, and the biostratigraphic range of the placoderm Phyllolepis is shown to extend down into the Frasnian stage of the Upper Devonian, thereby predating its appearance in Europe. These results have been reported in an appendix to a paper by ANU and Macquarie University staff, submitted to the journal of the Geological Society of Australia, in which Devonian sediments and volcanics in the region are described.

A new fish locality of probable Middle Devonian age was discovered by the Tantangara field party in 1975 in the Hatchery Creek Conglomerate near Wee Jasper, NSW., and some 308 specimens from there were identified, prepared, and catalogued. Systematic descriptions of this fauna are nearly complete, and will be published in a joint paper with J.D. Gorter (ex-BMR, now ESSO). This fauna is significant in being the first Middle Devonian fauna of European aspect yet discovered in Australia; it contains three new placoderms, rhipidistians, acanthodians and thelodonts. The thelodonts have been referred to the genus Turinia, previously known from putative Lower Devonian rocks in the Canning and Georgina Basins, and recognised as a Late Silurian/Early Devonian Zone fossil in Europe. The description of this fauna will provide a reference point for the correlation of other Devonian vertebrate occurrences in Australia.

Acid preparation of limestone material from Taemas/Wee Jasper was largely completed during the year, and a comprehensive suite of vertebrate microfaunas through the sequence has been prepared and catalogued. Progress on acid preparation of the Gogo collection (Canning Basin) was limited by lack of technical staff, but a number of lung-fish skulls were prepared at the ANU for study by Dr K.S.W. Campbell.

Additions to the collections during the year include the Hatchery Creek Conglomerate material mentioned above, various specimens from the lime-stones around Burrinjuck Dam collected during a period of low water levels early in the year, and material from the Eden/Pambula region of the NSW south coast. In addition, material from the Middle Devonian of Scotland and casts of type material from various European museums were identified and catalogued, part of the Antarctic collection was rearranged, and the whole of the 1972 Canning Basin, 1973 Amadeus Basin, and 1974 Georgina Basin collections were reorganised. The 1977 Georgina Basin collection was unpacked, sorted and stored. Preparation of Georgina Basin material commenced during the latter part of the year (see Project Branch report).

PALAEONTOLOGICAL LABORATORIES

During the year 954 samples were washed for microfossil examination, 1144 thin sections prepared, and 97 samples polished. Six hundred and twenty-seven slides of nannofossils were prepared from 306 samples. In the acid laboratory, Fyshwick, 550 samples totalling 2200 kg were processed for extraction of conodonts and 600 samples picked for ostracods. The palynological laboratory prepared 152 slides from the 126 sampdes processed.

Macropalaeontological work included the preparation of 120 large thin sections, the serial sectioning of 50 stromatolites, the mechanical and acid préparation of 300 fossil fish samples, the making of more than 2000 rubber replicas or plaster casts of fossils, and the picking of 2.5 tonnes of material for mammal remains.

ESCAP STRATIGRAPHIC ATLAS (IGCP Project 32)

STAFF: V.L. Passmore, C.M. Brown

The ESCAP (UN Economic and Social 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 a series of sheets showing correlated stratigraphic columns at 1:25 000 scale within Australian basins. Accompanying explanatory notes outline the stratigraphic and structural evolution of the basins and describe the geological setting of known and potential resources.

In 1978 atlas sheets and notes were prepared for the Carnarvon, Laura, Sydney, Carpentaria, Karumba, Bonaparte Gulf, Money Shoal and Arafura Basins (Fig. S4). The Carnarvon and Laura Basin compilations are to be included in a volume of atlas contributions to be published in late 1978. The

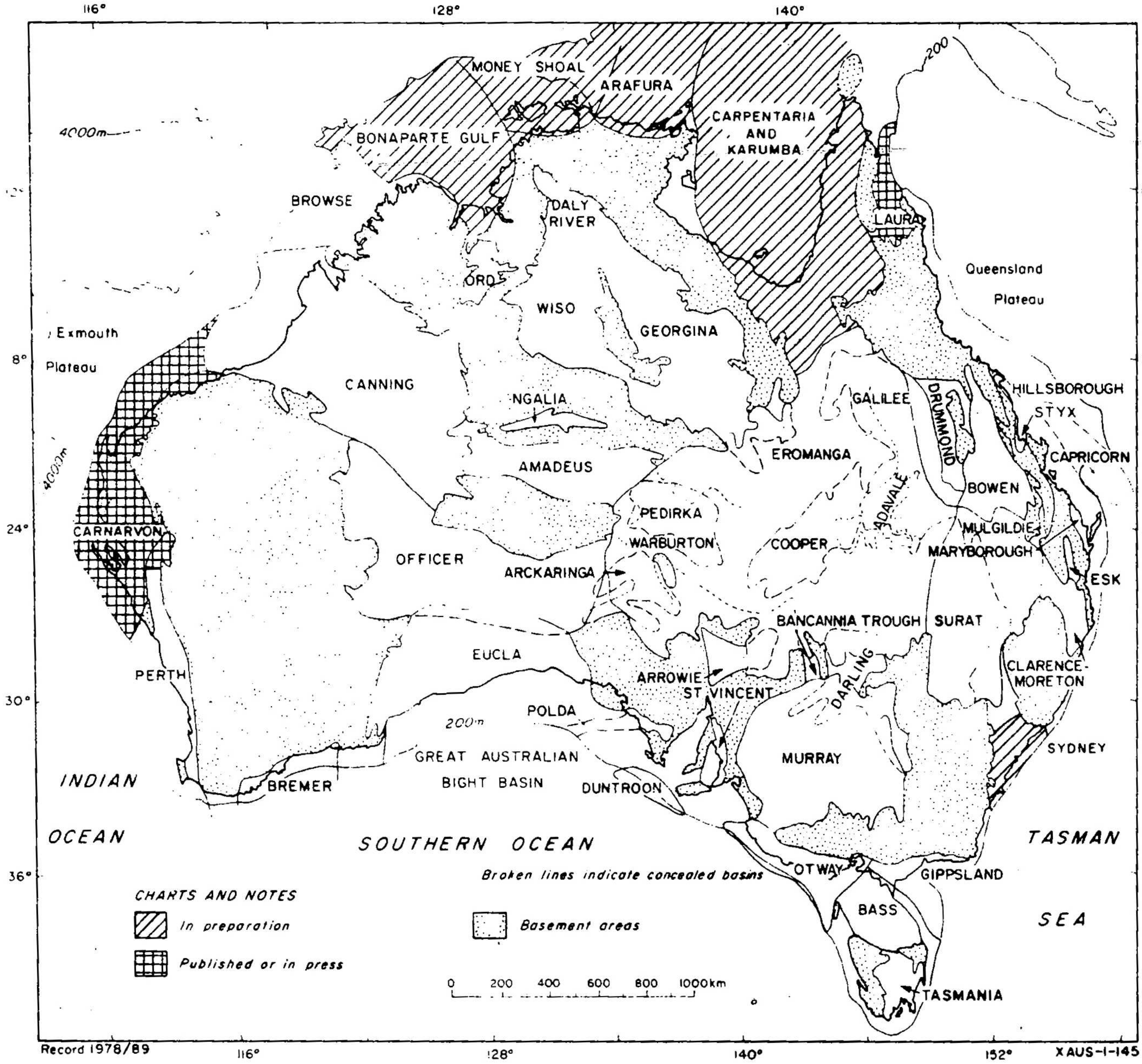


Fig.S4 Basins for which stratigraphic atlas contributions have been prepared.

project is envisaged to continue for the next few years in order to complete the large number of basins in Australia.

Throughout the year H.F. Doutch was seconded to ESCAP in Bangkok as stratigrapher in charge of co-ordinating the project throughout the region.

GEOLOGICAL SERVICES SECTION

Head: E.K. Carter

GENERAL

Engineering geology activities relating to the growth of Canberra remained subdued but a number of problem-solving hydrogeological and other studies were undertaken. The Section, with others, reviewed and made critical comments on several draft environmental impact statments; contributions were also made to other environmental planning studies. Some contributions were made to foreign aid projects, and the production of geological maps in the A.C.T. continued.

Twenty-three maps were edited by the Map Editing and Compilation Group. Work continued on a wide range of maps being compiled for publication by BMR or others, but progress has been less than had been hoped.

The study of the geology of mineral deposits was resumed in the latter part of the year when a start was made on the study of fluorite.

The Central Registry of Stratigraphic Names and Definitions was maintained; current literature was searched, bimonthly variations lists issued, and enquiries dealt with.

Two rare mineral species from new localities were identified by the Museum curator: pseudomalachite from near Tottenham, N.S.W., and kornerupine from central Australia. Numerous acquisitions by exchange, purchase and donation were made during the year. Further progress was made with cataloguing collections, and the usual information and education services were maintained throughout the year.

More than 5000 samples were handled by the Transit Room officer who is responsible for arranging for the preparation and examination of samples.

The Section Head visited the Australian Atomic Energy Commission's Research Establishment and CSIRO's Division of Applied Geomechanics. He represented the Bureau at several Inter-Departmental and other Committee meetings. He participated in the review of several environmental impact statements, maintained an awareness of the technology of geological disposal of nuclear waste, supervised the finalisation of a booklet of symbols for use on geological maps, and dealt with stratigraphic nomenclature matters as they arose.

ENGINEERING GEOLOGY AND HYDROLOGY

STAFF: E.G. Wilson, G. Jacobson, D.C. Purcell, G.A.M. Henderson, P.D. Hohnen, P.H. Vanden Broek, W.R. Evans.

Technical Officers: J.R. Kellett, G. Sparksman.

Technical Assistant: A.W. Schuett.

Field Assistants: D. Guy, R. McPake.

GENERAL

Many investigations reported below were carried out jointly with the Engineering Geophysics Group with which a close liaison was maintained. All seismic surveys referred to, unless otherwise indicated, were carried out by the Engineering Geophysics Group.

Locations of projects in and near the A.C.T. referred to in the text are shown in Fig. G1. Some projects are shown by number and are identified in the text by the corresponding number.

During the period under review the Subsection produced 53 reports, mostly as Records or Professional Opinions. Thirty-three were published or issued; the remainder are at various stages of editing and reproduction. Included in the numbers are 11 restricted reports which are not listed under Publications and Records. Two maps for publication are with the Editors, or have been edited.

A number of reviews of Environmental Impact Statements on projected mining and milling projects were prepared for the Department of Environment, Housing and Community Development. These reviews contained contributions from chemists, mining engineers and hydrogeologists as well as the engineering geologists within the Bureau. E.G. Wilson attended a workshop at Jabiru, Northern Territory, organized by the Office of the Supervising Scientist. The purpose of the workshop was to advise on research projects and monitoring programs suitable for the environmental assessment of the impact of the mining and milling of uranium on the South Alligator River Region.

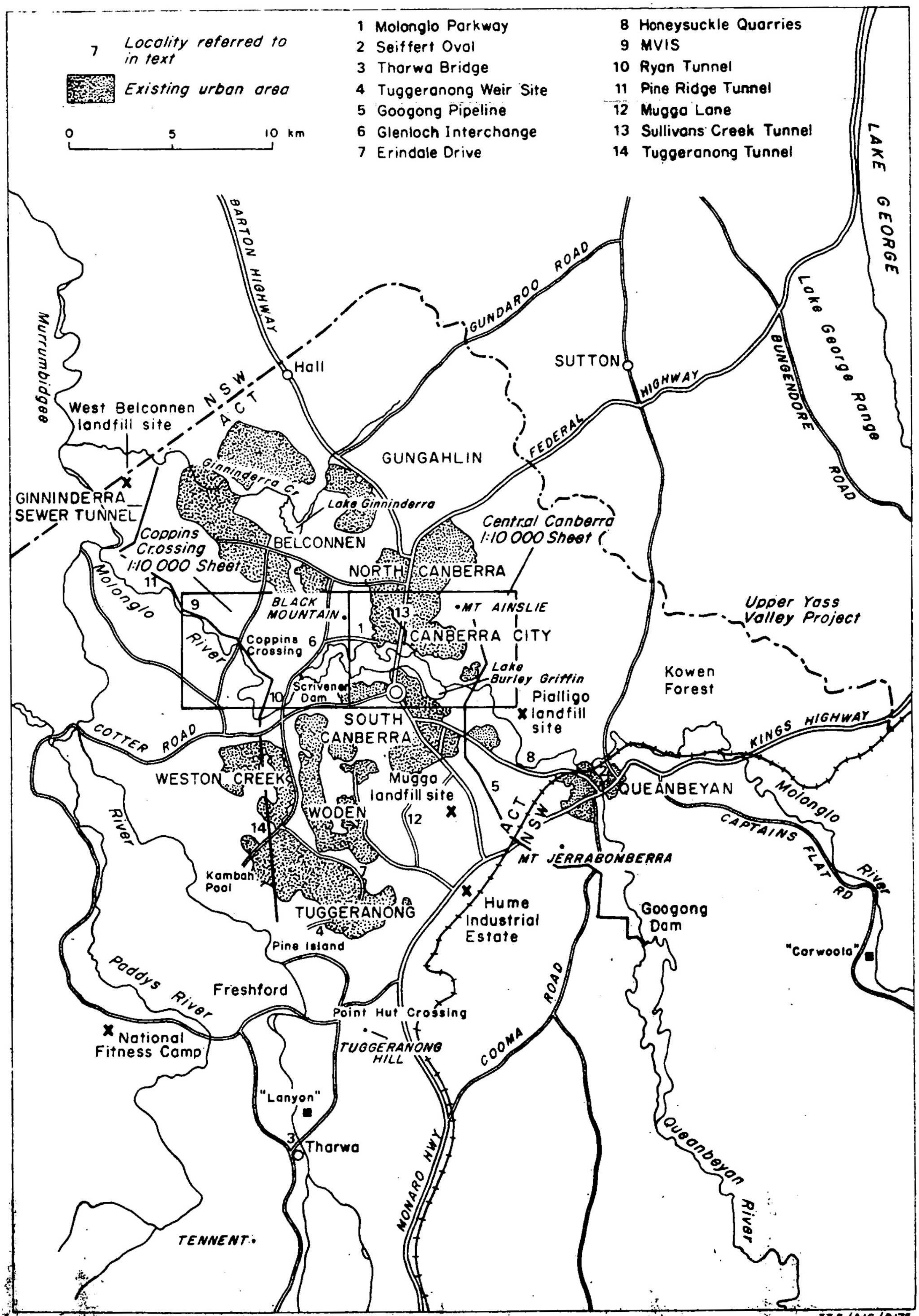


Fig. G1 Engineering geology and hydrology; locations of projects, Canberra and adjacent areas, 1978

ENGINEERING GEOLOGY FOR CANBERRA'S SEWERAGE AND WATER SYSTEMS

by

P.H. Vanden Broek and E.G. Wilson

Engineering geology services for the investigation, design and construction of new works for Canberra's sewerage system were provided for the Department of Construction and the National Capital Development Commission (NCDC).

GINNINDERRA SEWER TUNNEL

The project was described in the Branch's Annual Summary for 1977; its purpose is to link the Belconnen sewerage system to the Lower Molonglo Water Quality Control Centre. Tunnel excavation continued throughout the year from station 3350 to station 290, a total of 3060 m of 3 m diameter tunnel. All excavations, including shafts 1, 2 and 3, were completed by 21 September 1978, six weeks ahead of schedule.

Mapping of the tunnel was carried out as excavations progressed; particular note was made of rock conditions, support used and groundwater inflows. Tunnelling conditions ahead of the face were predicted where sufficient data were available.

Rock types intersected include granite porphyry, sandstone, shale and dacite tuffs and flows. Bedding of the tuffs and sediments indicate that the sequence was gently folded and intruded, mostly by sills or plugs. Excavation conditions were generally as good as was expected: 22% of the rock excavated in the upstream heading required steel support.

Groundwater inflows were generally slight: they were no more than a nuisance to the contractor. The cumulative total for the upstream section (about 4300 m) was about 36 000 litres per hour. Significant groundwater inflows adjacent to faults and seams will become pressure-grout targets once the tunnel has been lined with concrete.

SULLIVANS CREEK SEWER TUNNEL

The purpose of the Sullivans Creek Sewer Tunnel is to convey sewerage from the three trunk sewers in the Sullivans Creek catchment to the pumping station at the north end of Commonwealth Avenue Bridge. At present this is done by the N2 and N3 sewers; however peak wet weather loadings of 55 Ml/d (megalitres per day) exceed the unsurcharged capacity of existing facilities (38.5 Ml/d) resulting in uncontrolled overflows near the mouth of Sullivans Creek.

The tunnel is likely to be about 2 m in diameter and approximately 2 km long with manholes about every 200 m. Drilling for the design investigation has been completed; in all twenty-one diamond core holes of average depth about 12 m were drilded by contractors. Several seismic traverses were carried out and vibration tests were done to determine the upper limit of blasting that can be carried out (Results indicate that 6 lb per delay will probably be an acceptable upper limit to blasting).

Sections are being plotted to show the geology, and drilling and seismic results. Construction is scheduled to start in the current financial year. A preliminary (pre-drilling) feasibility study is reported in Record 1978/24 and a report on subsequent investigations has been prepared, but not issued.

COMPLETION REPORTS

Completion reports on Tuggeranong Sewer Tunnel (Record 1977/68), the Molonglo Valley Interceptor Sewer (Fig. G1, locality 9; Record in preparation), including Ryan and Pine Ridge Tunnels (localities 10 and 11), and Googong Dam and reservoir (two Records, in preparation) were written or issued during the year.

MELBOURNE TELECOM TUNNELS

Engineering geological services have been provided for the design of 1881 m of cable tunnels and connecting chambers beneath Queen, Lonsdale, Russell, Exhibition and Rathdowne Streets in central Melbourne for the Department of Construction, Victoria-Tasmania Region. The relatively shallow tunnels, with cover up to 9 m, will be driven through weathered Dargile Formation (Silurian); Werribee Formation, the Older Volcanics and Brighton Group (Tertiary); and the Elizabeth Street Formation and a thickness of colluvium ranging to 14 m near Russell Street (Quaternary).

The results of the investigation and drilling (30 holes) undertaken in 1977 were reported in a BMR Record. Additional drilling (13 holes) in August 1978 has added to our geological understanding of the project and a supplementary report, BMR Record 1978/90, was issued in October.

More than 50 percent of the tunnel will be in poor rock which includes alluvium, weathered basic dykes, poorly consolidated sediments, fault zones and extremely and highly weathered mudstone. The tunnels are expected to require support throughout most of their length, and the excavation methods are likely to include hand mining, mechanical excavation and drill and blast. The presence or absence of groundwater in the poorly consolidated Cainozoic sediments will greatly influence the means of excavation.

SUVA SEWERAGE TUNNEL, FIJI

A review of the inlet portal location and design was undertaken and some geophysical traverses made. The report was finalised in May 1978.

CANBERRA MAPPING PROJECTS

by

G.A.M. Henderson

ENGINEERING GEOLOGY MAPS, SCALE 1:10 000

Work was concentrated mainly on completing a compilation of the Central Canberra Sheet and preparing the explanatory notes and figures. Some alterations to the format of the Coppins Crossing Sheet were made. It is now proposed to publish the explanatory notes of this, and other, sheets as a separate booklet rather than on the back of the map as previously proposed.

GEOLOGICAL MAP OF CANBERRA-QUEANBEYAN, SCALE 1:50 000

A compilation at 1:50 000 scale of the geology of Canberra and Queanbeyan, with explanatory notes, was completed and forwarded to the map editor.

GEOLOGICAL RECORDS

The recording of exposures and remapping within the urban area was undertaken wherever possible. Excavations during construction of the Molonglo Parkway (locality 1) exposed the conformable contact between the Black Mountain Sandstone and the State Circle Shale at the southern foot of Black Mountain, and a high-level silt and gravel deposit nearby showing soil features indicative of considerable (probably pre-Quaternary) age (Henderson - Record in preparation). Widening of the Barton Highway near Ginninderra Creek exposed the faulted contact between the Canberra Group and State Circle Shale.

HYDROGEOLOGY, A.C.T. AND ENVIRONS

by

W.R. Evans, P.D. Hohnen, G. Jacobson & J.R. Kellett

Included under 'Hydrogeology' are groundwater resource studies, an hydrogeological study of the groundwater component of a minor basin, drainage problems, the pollution of groundwater and hydrological data-recording activities.

A.C.T. GROUNDWATER RESOURCES

Hydrogeological advice was provided to landholders, drilling contractors and organisations in urban areas that have high annual water consumption. Sites for farm water-supply bores were selected on airphotos and oral advice given to primary producers in the A.C.T. and environs. Requests for groundwater supplies were received from several Canberra golf clubs for watering of greens and fairways: bores were sited in areas where suitable aquifers were expected. A preliminary assessment was made of groundwater resources that could be exploited for watering on the Australian National University campus (Professional Opinion Geol. 75/013). Discussions were held with drilling contractors on all aspects of groundwater supplies in the A.C.T. and environs: this interchange of information assists both the contractors and the Engineering Geology Sub-Section which is preparing a hydrogeological map of the A.C.T. and environs, at 1:100 000 scale.

Work commenced on updating the A.C.T. water bore computer data file, preparatory to compilation of the hydrogeological map.

Three bores were sited by BMR and drilled under Bureau supervision for the Department of Construction at the new National Fitness Camp at Tidbinbilla. The requirement was for 2 bores (one for back-up purposes) each with a yield of 2.5-5.0 m^3/hour. One bore was abandoned due to caving in of overburden. One bore gave a yield of more than 18 m^3/hour and the other more than 5 m^3/hour. Water quality is exceptionally good for A.C.T. groundwater, with a total dissolved solids content of only 290 mg/1. The bores will be equipped with pumps for supplying the total water requirements of the camp.

A bore was sited at the Kowen Forest for a water supply for the settlement. The bore was drilled by others to 61 m, and was pump-tested. It gave a yield of 4.5 m^3/hour; the total dissolved solids content was 1100 mg/1, which presents some problems for household use in hot water systems.

RADIOACTIVE WASTE MANAGEMENT, WEST BELCONNEN

At NCDC's request, the group assessed the geological feasibility of storage and disposal of short-half-life, low-level, radioactive waste at the West Belconnen landfill site. Three bores were drilded and cored to a depth of 20 m, and aquifer tests were carried out to measure hydraulic constants. Infiltration tests were made in soil materials overlying weathered fractured porphyritic dacite at the proposed disposal site. The nearest probable discharge point of groundwater originating beneath the disposal site, was found to be about 1 km west of the site. Travel times for radioactive wastes that could reach aquifers below the site and discharge as stream flow 1 km west of the site, were calculated from aquifer parameters to be 20 ± 5 years. Recommendations made to NCDC include packing wastes in absorptive materials in stainless steel drums (Record 1978/83).

UPPER YASS RIVER CATCHMENT STUDY

The Sub-section is undertaking jointly with CSIRO, a study of the upper Yass River valley catchment which has been designated a Representative Basin by the Australian Water Resources Coouncil. One of the main objectives of the study is to determine the movement of elements within the hydrologic cycle of the basin. The Sub-section's work is aimed at defining the subsurface component of the basin's hydrology. Modelling techniques, namely numerical analysis, will be employed to gain some predictive input to the project.

The small catchment being studied is about 300 ha in area, and has a relief of 130 m. The hydrogeology of the catchment can be summarised as a fractured rock aquifer in Ordovician sediments, and a surface aquifer in alluvial and colluvial surficial cover. A network of 12 deep bores and 60 shallow piezometers has been provided to enable CSIRO to sample the groundwater in the two aquifers and determine its chemistry. Additional to this sampling, use will be made by BMR of the holes and their core-logs to conduct research into the mechanics of fractured rock aquifers.

GROUNDWATER POLLUTION STUDIES

Hydrocarbon pollution of groundwater in Canberra was further investigated. Spreading of the pollution plume in the Bunda Street, Canberra City, area (see 1977 Annual Summary) down the hydraulic gradient was monitored by means of a network of observation bores. A recovery well 13 m deep was constructed adjacent to a bore 30 m deep. Water was pumped from the bore to induce a core of depression in the potentiometric surface over the area of the pollution plume. An oil-skimmer, using a stainless steel conveyor belt, was installed in the recovery well and the pollutant - petrol - was removed to an underground storage tank. After four months' continuous pumping, some 1100 litres of petrol had been recovered and the down-gradient end of the pollution plume had been substantially cleared up. A series of groundwater tracing experiments using fluorescent dyes was conducted in the bores in conjunction with the A.N.U. Centre for Resource and Environmental Studies (Record 1978/86).

At the Hume Industrial Estate, Jerrabomberra Avenue, a network of 15 bores was constructed to monitor groundwater pollution by effluent from a timber mill. Pollution was detected.

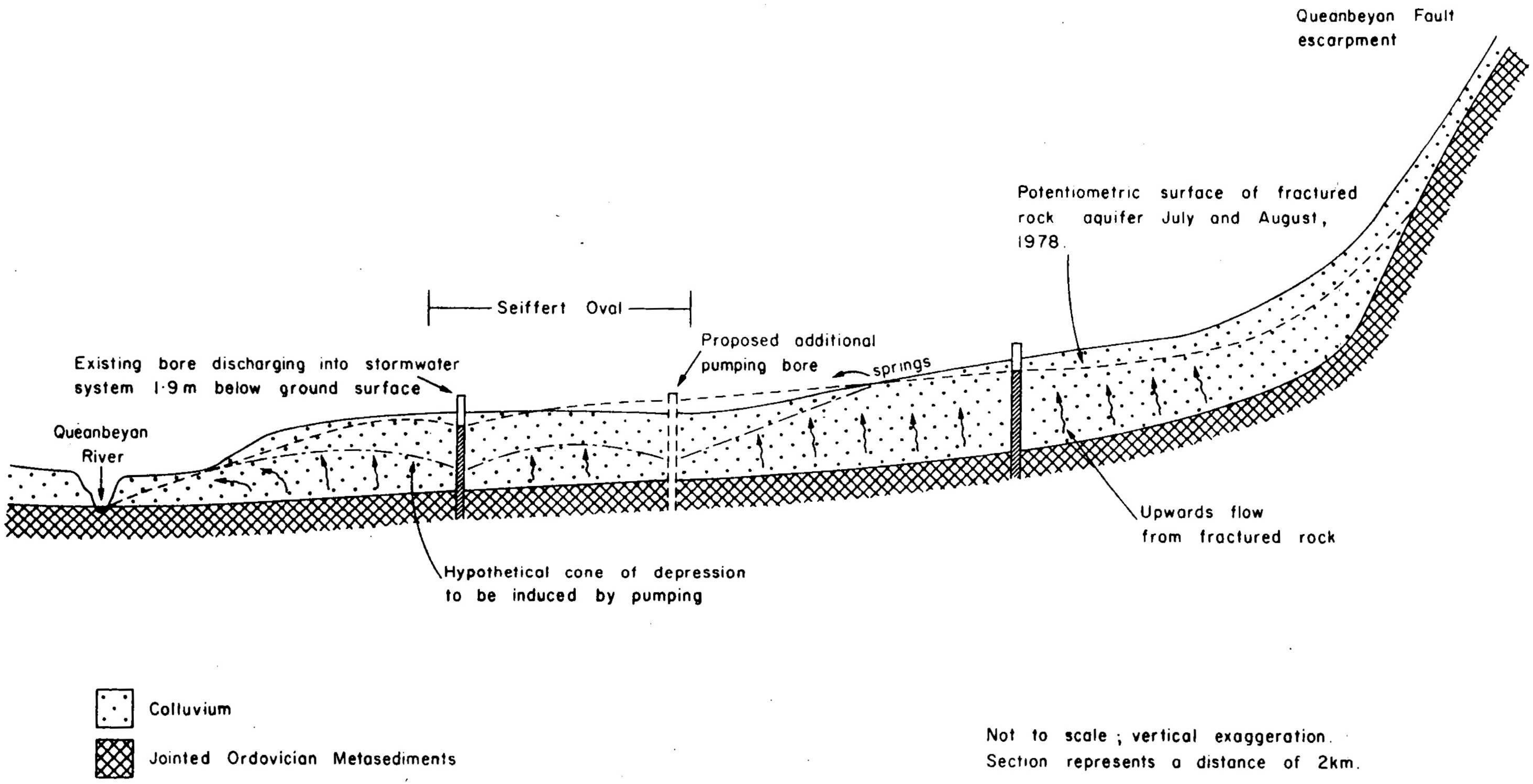
Groundwater surveillance continued at three sanitary landfill sites in the A.C.T. and an extensive pollution plume was detected at the oldest operating site.

DRAINAGE INVESTIGATIONS

Excessive waterlogging at Seiffert Oval, Queanbeyan (locality 2), precluded use of the oval for recreational purposes during July and August, 1978. The waterlogging is caused by upwards flow from fractured Ordovician metasediments through the overlying clays and colluvium. The groundwater potential was above ground su-rface following high recharge during the early winter, consequently water penetrated upwards to the surface (Fig. G2). BMR recommendations for remedial drainage were to create a cone of depression beneath the oval by pumping from wells. Subsequent pumping from the existing irrigation bore, and the construction of and pumping from a new bore on the other side of the oval, appear to have solved the problem.

LAKE GEORGE, N.S.W.

Monitoring of Lake George continued with monthly gauging of lake level and salinity. The results of 20 years' monitoring were compiled and analysed, and a 20-year water balance for the lake was derived. During the year the maximum depth of Lake George ranged between 2.5 and 3.0 m and salinity was about 2000 mg/l.



Record 1978/89

155/A16/2176

Fig G2 Waterlogging at Seiffert Oval Queanbeyan, caused by upward flow from fractured rock. Schematic section looking north.

SOUTH SUMATRA GROUNDWATER INVESTIGATIONS

by

G. Jacobson

Advice was given throughout the year to the Department of Construction in connection with groundwater investigations for town and village water supplies in South Sumatra, Indonesia. The detailed hydrogeological investigation is being done by consultants as part of the Australian aid program to Indonesia.

SOIL STRATIGRAPHIC STUDIES

by

J.R. Kellett

A long-term study is being carried out on soils and weathering profiles in the Canberra region with particular emphasis on hillslopes and their colluvial mantles. The aim of the investigation is to identify unique diagnostic pedological features, for each weathering surface, that are readily apparent in hand specimen. Investigations are centred around type areas in the three main rock provinces around Canberra: acid volcanics, granite and Palaeozoic metasediments.

The type area for the acid volcanics is the hillslopes and pediplain basins of 'Lanyon' Station, in the southern Tuggeranong valley. A tentative table has been prepared of sola and subsola criteria for the three oldest basin groundsurfaces and their associated colluvial weathering surfaces. Mineralogy of the clays and subsolum plasma was determined by X-ray diffraction and grain morphologies, and size distributions were analysed for indications of sedimentary environments. These studies indicate a period of aridity with active fan-building during the late Tertiary. This appears to have been succeeded by a phase of periglacial fan development followed by, a probably climatologically significant, aeolian accretion to the Canberra landscape during the early Pleistocene. Pedogenesis during early to middle Pleistocene appears to have taken place under humid conditions.

The volcanic province study has been extended to include the slopes adjacent to Mugga Lane (locality 12) where good profiles are being temporarily exposed in refuse disposal trenches. The study area for Silurian sediments is the hillslopes of Mount Jerabomberra where little field mapping has been done so far.

REVIEW OF ENVIRONMENTAL IMPACT STATEMENTS

by

E.G. Wilson

The environmental impact statements and management programs proposed for the following projects were assessed, and Professional Opinions, incorporating comments in the various areas of Bureau competence, were forwarded to the Department of Environment, Housing and Community Development.

Nabarlek uranium project, N.T. (Prof. Opin. Geol. 78.004)
Jabiluka uranium project, N.T. (Prof. Opin. Geol. 78.005)
Metallurgical research plant, Kalgoorlie, W.A.
(Prof. Opin. Geol. 78/009)
Wagerup alumina project, W.A. (Prof. Opin. Geol. 78/014)
Yeelirrie uranium project, W.A. (Prof. Opin. Geol. 78/017)
Worsley alumina project, W.A. (Prof. Opin. Geol. 78/020)

MINOR PROJECTS

Brief reports were prepared or advice tendered on many minor peojects in the A.C.T. for our various clients. The projects are briefly listed below.

Queanbeyan Telephone Exchange Advice on foundation material and the logging of drill core was undertaken for the Department of Construction.

Tharwa Bridge (locality 3) Geological and geophysical investigations for foundations for a new bridge were carried out at six sites for the Department of Construction. All sites would provide satisfactory foundations (Record 1977/65).

Tuggeranong Weir Site (locality 4) Mapping of the excavations for a 4-metre high weir was undertaken and advice tendered on foundation conditions to the Department of Construction.

Googong Pipeline (locality 5) Excavations for the pipeline from Googong Dam to Campbell reservoir were mapped and a report presented to the Department of Construction. The locations of a number of faults and lithological boundaries were clarified, and the excavation conditions were found to be in general agreement with those outlined in the investigation report (Record 1978/84).

Glenloch Interchange (locality 6) Slope stability was assessed and reported on to the Department of Construction during construction of the interchange. Slope recommendations were made to ensure control of block toppling.

Wollongong Lighthouse The stability of the headland on which the lighthouse is located was assessed and a report prepared for the Department of Construction, N.S.W. It had been suggested by others that joints in the cliffs may pose a threat to its stability. The report concluded that whilst general erosion of the headland with block toppling would continue, the lighthouse was stable for many years to come.

Erindale Drive (locality 7) Slope stability was assessed and a report made to the Department of Construction. Instability was caused by close jointing and ravelling of the material; safety fences were proposed and surveillance recommended.

Honeysuckle Quarries, Pialligo (locality 8) The Honeysuckle quarries were mapped and a report on stone reserves prepared for the Department of the Capital Territory.

Tuggeranong Hill The stability of the southwest slope of Tuggeranong Hill was assessed, and extensive areas of landslip debris fans were mapped below the change of slope at the foot of the hill. A number of large isolated boulders on the steep slope are potentially unstable, and chaotic blocks in the landslip debris at the foot of the slope would make excavation for services costly. As a foundation material, the debris slopes are likely to exhibit uneven settlement. A report was prepared for NCDC.

MAP EDITING AND COMPILATION

by

G.W. D'ADDARIO

STAFF: G.W. D'Addario, W.D. Palfreyman (on long service leave from 1 July), L. Emmett (from 3 July to 16 August), P.D. Hohnen (from 25 September) J. Mitchell, N.D. Knight (to 24 July), J.M. Bultitude, A. Mikolajczak, D. Jongsma (part-time from December 1977 to April 1978).

Advice was given to various authors and draftsmen on aspects of map compilation for the preliminary and coloured series and for special maps. Map committee meetings to review progress, priorities and program were held on 8 February and 27 June. Further amendments and corrections were introduced in the Standard Geological Symbols Booklet (now titled 'Symbols for Geological Maps'). Printing is in progress and copies will be distributed at the next Government Geologists' Conference on 27-28 November '78.

MAP EDITING

Twenty three maps were edited:

1:250 000 Geological Series - colour edition - 4 maps: Morris, Runton, Kikori, Noonkanbah.

1:100 000 Geological Series - colour edition - 8 maps: Prospector, Kennedy Gap, Quamby, Hedleys Creek, Seigal, Rum Jungle, Tantangara, Brindabella.

1:50 000 Geological Map - 1 map: Canberra (ACT) Queanbeyan (NSW) and adjoining areas.

1:10 000 Engineering Geology Series - 1 map: Coppins Crossing.

1:500 000 Geological Maps - 2 maps: Burdekin River Region, Pine Creek Geosyncline.

1:1 000 000 Geological Maps - 3 maps: Carpentaria, Karumba and Laura (part only) Basins (Plates 1 and 2); Southern Queensland and Northern New South Wales shelf sediments.

BMR Earth Science Atlas, 1:10 000 000 - 3 maps of Australia: Main structural elements, Solid geology, Drainage and continental margin.

Circum Pacific Map Project, 1:10 000 000 map - 1 map: Geology of Australia and the continental margin.

MAP COMPILATION

BMR EARTH SCIENCE ATLAS

Further progress was made with compilation and preparation for printing of the initial maps for the Atlas. The fair drawing of the Main Rock Types, Cainozoic and Weathering and Major Structural Units maps was completed and checked. Tenders have been called for printing these three maps and the Drainage and Continental Margin map. Serious delays are occurring in the writing of the accompanying one-page commentaries. Notes for the Main Rock Types Map (L.E. Emmett) and Cainozoic and Weathering map (G.W. D'Addario) are being written.

Additional maps for the Atlas are being produced by the Geophysical Branch. All the maps referred to here are at scale 1:10 000 000 unless otherwise indicated.

General Geology - Australia (G.W. D'Addario, W.D. Palfreyman, J.M. Bultitude)

Compilation of the map was completed; the map will receive a final edit in November 1978. It is not now intended to include the map in the Division of National Mapping's Atlas of Australian Resources.

Solid Geology - Australia (G.W. D'Addario, W.D. Palfreyman, J.M. Bultitude)

Cainozoic rock, other than major sequences, are omitted, giving as far as possible, a portrayal of the bedrock geology of Australia. The map has been compiled and fair-drawn and final editing is in progress.

Mineral Occurrences - Metals (N.D. Knight)

The data base for this map has been completed and preparation of the map, which will be done in part by automatic plot of the data, has started. A series of 1:30 M maps will also show the geological setting of commodities.

ATLAS OF AUSTRALIAN RESOURCES, 3rd Series, by Division of National Mapping

Geology of Australia 1:5 000 000 (G.W. D'Addario, J.M. Bultitude)

Compilation of the map is well advanced, but completion is dependent on discussions with officers of the Division of National Mapping (DNM). The map will be fair drawn by DNM.

ESCAP STRATIGRAPHIC ATLAS

Australia: Sedimentary Sequences 1:10 000 000 map (G.E. Wilford, J.M. Bultitude).

This map shows the time of initiation of widespread sedimentation, predominant ages of basement provinces and time range of sedimentation and tectonic events. Compilation is almost complete. The map will be adapted for the BMR Atlas and the Circum-Pacific Map Project.

COMMISSION FOR THE GEOLOGICAL MAP OF THE WORLD (with note on Paris meeting by R.J. Tingey)

J.N. Casey, Vice President, Australia and Oceania, of the I.U.G.S. Commission for the Geological Map of the World was represented at the Commission's March 1978 meeting in UNESCO Headquarters, Paris, by R.J. Tingey, who was on leave at the Scott Polar Research Institute, Cambridge, United Kingdom, at the time.

C.G.M.W. provides a forum for representatives of the world's geologists to meet, learn of the work of each other's countries, and co-operate in the production of geological and related maps and reports. Besides sending delegates to meetings, Australia has contributed to Commission activities by arranging for the printing of a number of its maps.

At the meeting geological, tectonic, and metamorphic maps of Antarctica, as compiled by Soviet geologists, were displayed and discussed, and progress with compilation of the world metallogenic map was reviewed. To date CGMW has concerned itself largely with maps of land areas, but geological maps of oceanic areas were given much attention at the Paris meeting, a sea-floor map of the Pacific Ocean serving as prototype. Lengthy meetings also considered progress with the International Tectonic Map of the World.

Metamorphic Map of Australia 1:5 000 000 (T.G. Vallance)

A compilation by Professor Vallance, University of Sydney, was recompiled with BMR amendments, circulated to State and Territory Geological Surveys for comment, and revised. The second draft was returned to Professor Vallance with comments. Discussions are to take place shortly on the final draft.

CIRCUM-PACIFIC MAP PROJECT - SOUTH-WEST QUADRANT

Geology - Australia 1:10 000 000 (G.W. D'Addario, W.D. Palfreyman, J.M. Bultitude - onshore; D. Jongsma - offshore).

The compilation of the map was completed, and the material was sent to compilers of the Quadrant map, and to others.

BULLETIN 180 - Notes to accompany the Geological Map of the Northern Territory, scale 1:2 500 000 (G.W. D'Addario).

The first draft is at an advanced stage of writing.

BULLETIN 181 - Notes to accompany the Geological Map of Australia 1:2 500 000 (to include 4 coloured maps at 1:10 000 000 scale) (G.W. D'Addario, W.D. Palfreyman).

The first draft has been largely written.

INDEXES, TECHNICAL FILES AND MINERAL REPORTS

by

K. Modrak

STAFF: K. Modrak, L. Kay, P.D. Hohnen (November), B. Jones (from 10 July), A.P. Langworthy (part time to April), P.J. Kennewell (from 12 June, excluding period 14 July-22 September).

STRATIGRAPHIC INDEX

Literature on Australian geology received through the Bureau library was indexed under the headings - stratigraphic name, author, 1:250 000 Sheet area, basin name and subject. Copies of the various index cards were sent to the Bureau library, BMR Basin Study Group and State Geological Surveys as requested.

New stratigraphic names were added to the Central Register of Stratigraphic Names and all references to these and previously published names were added to the card index. Some 229 new names, 100 of which were previously reserved, and 46 definitions of units were indexed. In the same period 197 new names were reserved for use and 47 definition cards submitted by authors, through Divisional Stratigraphic Nomenclature Subcommittees of the Geological Society of Australia, were filed.

Bi-monthly Variations Lists and the annual Deletions List, 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 handled.

Information for the compilation of the annual report to the Council of the Geological Society of Australia for the period December 1976 - December 1977 was sent to Mr H.R.E. Stains, Convener for the Stratigraphic Nomenclature Committee. Statistical information was also collated and sent to the Convener for presentation at the Stratigraphic Nomenclature Committee meeting held in Townsville in August.

TECHNICAL FILES

The technical data storage system known as Technical Files is not being updated with current information but is available for reference.

MINERAL REPORTS AND MINERAL INDEX

P.J. Kennewell started work on a study of the occurrence of fluorite in Australia. A report will be produced for publication in the Mineral Reports Series.

No work was done on the mineral index.

MUSEUM AND TRANSIT ROOM

STAFF: D.H. McColl - Mineralogist/Curator
J.E. Price - Technical Officer - since 12/12/77
J.D. Reid - Technical Assistant/Cataloguer
M.S. Amar - Technical Assistant/Transit Officer

MUSEUM
by
D.H. McColl

COLLECTIONS - Two mineral discoveries were the highlights of mineralogical research this year. Firstly, the discovery of pseudomalachite, an extremely rare basic copper phosphate, was made at an old mine site near Tottenham in central N.S.W. Such spectacular massive botryoidal pseudomalachite of this grade has only been reported from the Urals and from South Africa, neither of which sites now produce specimens. Secondly, crystals of kornerupine, a metamorphic aluminium borosilicate, were discovered in conjunction with mapping work being done by R.G. Warren of the Arunta Party, at a site in the Harts Range of Central Australia. Large euhedral crystals of kornerupine have previously only been reported from the high grade metamorphic suites of Greenland.

Further acquisitions by donation, purchase, exchange or field collection also enhanced the collections. Notable among these were: the purchase in March of a fine display specimen of pyromorphite from one of the classical French sites; the purchase in December of two diamond crystals, set in pebbles of kimberlite host rock, from the Mir Diamond Pipe in Russia; and the acquisition by exchange in January of a crystal of kornerupine in matrix from Greenland. A further exchange, using surplus malachite-cerussite obtained last year in Northern Territory, resulted in the addition to the BMR collections of a fine crystal group of pyrite from the Peruvian lead-zinc mines. The pyrite is valued at $900 and is a superb showpiece.

By donation from Mr G. Morrison of Glen Innes, we received a suite of the various non-metallic minerals of the New England mining district in northern N.S.W., which are poorly represented in our collections. An unusual beryl crystal from the Harts Range in Central Australia was also donated by Mr J. Bruce, of Alice Springs. Its rarity is due to a gross degree of twinning in the prism zone, which by repetition of the faces produces a form which is virtually cylindrical.

Extensive specimen exchanges are also being made between the museum and the mineralogy division of Copenhagen University, which has sent to BMR suites from the metamorphic and mineralised provinces of Greenland, in return for a wide range of Australian specimens.

Cataloguing and computer coding of all the major collections is now largely complete with the exception of the Doo Collection. This, our largest collection, has approximately 2,500 specimens, and was assembled as a type collection to illustrate the Dana mineralogical volumes which are the principal texts in the English language. This collection is being re-sorted and catalogued to conform with those texts, and although a tedious undertaking, is expected to improve the usefulness and accessibility of the collection.

RESEARCH - Intermittent effort has continued toward production of a publication concerning the secondary mineralisation of the copper-lead-zinc orebody at Brown's Deposit, near Rum Jungle in the Northern Territory. An article describing the pseudomalachite from Tottenham appeared in the June edition of the "Australian Mineralogist".

MUSEUM SERVICES - Mineralogical, gemmological and petrological enquiries requiring varied, but wide, technical expertise, continue to be received from the public, other government departments and BMR officers. Despite the relative inaccessibility of the museum room, and the absence of any publicity or notices directing visitors, there has been a constantly increasing demand for information services, which are otherwise only available in Sydney. Institutions using our services currently include the Canberra College of Technical and Further Education, the Canberra Gem Society, the National Museums Section of the Department of Home Affairs, the Consumer Affairs Bureau in the Department of the Capital Territory, the Department of Foreign Affairs, the Australian National University, the Bathurst Gold Mining Museum, the Queanbeyan District Scouts, the Australian-American Association, Macquarie University, and the Forest Research Institute in the Department of Primary Industry.

Outside Australia various enquiries or exchanges were undertaken with the Smithsonian Institution, Copenhagen University, Berlin University, and the Japanese Geological Survey to which BMR donated a plaque set with boulder opal as a uniquely Australian contribution to the display for the foyer of their new Geological Museum building.

EDUCATION - Requests continue to be received for school visits to the museum with a peak in August, when six groups came. Such visits cover a range of topics including physical properties of minerals, Australian ores, petrology of the Canberra region, and so forth. Some rapid setting-up and changing of internal museum displays have been necessary at times. Nine different A.C.T. schools availed themselves of our museum as well as Queanbeyan High and Sylvannia High, in surburban Sydney, a total of 405 students.

Some time was devoted to preparation for local excursions, including the local State Circle, and the more distant Taemas basin and the caves and alluvial minerals of Wee Jasper. Three days were spent at Marist College sorting the rock and mineral collection into a systemmatic and usable format.

Sorting the bulk collections from which the schools' rock and mineral sets are assembled continued during the year. New material has been received from the field and has been incorporated into the basic sets, nine of which were delivered to schools this year in response to written requests. Some miscellaneous specimens for display were also provided. A basic set, to cover most of the needs of secondary students, comprises 19 igneous rocks, 15 sedimentary rocks, 11 metamorphic rocks, 15 metallic minerals and 24 non-metallic minerals: a total of 84 specimens in each set.

The material stored for these sets, despite culling and simplification, is bulky and is therefore stored at Fyshwick. A small section is being organised to receive and store it in an orderly manner. The only materials in short supply are some of the metamorphic and sedimentary rocks which do not occur in the Canberra region.

<u>EXHIBITIONS</u> - In January a display featuring the showier pieces of Australian ores was prepared for long-term exhibition at the Australian Embassy in Washington. A small collection of ores was provided for inclusion in a display in the Minister's Tasmanian office. The topic of meteorites, tektites and extraterrestrial geology was chosen for our contribution to the Gemboree-78 exhibition, a nationwide annual gathering of amateur geological and lapidary enthusiasts, held during March at Gympie, in Queensland.

In September a collection of phosphate minerals was displayed at the 4th National Exhibition of Minerals, held at Glen Waverley, a suburb of Melbourne. Some purchases and exchanges were made.

<u>VISITORS</u>: - In-house displays provided by the museum continue to be limited to four showcases in the museum, which contain the most fragile displays, and a variable number of the remaining seven cases which are distributed around the corridors of the building. Currently three of these are in use by other sections of BMR. An average of fifty visitors sign the visitors' book at the museum each month, and most of these state that they have come merely to see whatever displays are available, which is surprising since there is no indication outside BMR that a museum is in the building. The total this year is nearly 600, which is a slight decrease from 1977; it does not include schoolchildren in escorted classes, or enquiries from BMR personnel.

TRANSIT ROOM

by

M.S. Amar

Field party samples requiring petrological, petrographic, analytical, radio-isotope, or other investigations are forwarded to contractors or the relevant Bureau Laboratories by the Transit Officer (Ms M.S. Amar). Efforts are still being made to incorporate this and other past and present project data into a single simple indexing system which can be computerised.

The total numbers of samples processed this year are as follows:

Thin sections	3,784
Polished thin sections	207
Unconsolidated thin sections	72
Impregnated thin sections	5
Age determinations (various)	88
Chemical analyses (various)	1,162
X-Ray diffraction determinations	112
Total	5,430

CONFERENCES AND COURSES

Members of the Section attended external (i.e. non-Public Service) conferences and courses as set out below. In addition, staff members attended various in-Service training courses, covering both management and technical subjects. Staff also participated in the summer staff lectures and several gave lectures on specialist topics to outside organisations. Several officers availed themselves of Public Service study grants and study leave provisions.

AMIC Seminar on 'Access to Minerals and Security of Tenure', held in Canberra, 3rd April: E.K. Carter.

Joint Aus.IMM-AIME Conference, 1978, on Minerals and Energy, held in Canberra, 15-17th May: E.K. Carter.

Inst. Engineers, Australia, Hydrology Symposium, held in Canberra, 5-7 September: P.D. Hohnen and W.R. Evans.

Third Australian Tunnelling Conference, held in Sydney, September 18-22: P.H. Vanden Broek.

Urban and Environmental Geology Symposium, held in Adelaide: 30 October - 1 November: E.G. Wilson and W.R. Evans.

AMF Workshop and Seminar on Information Storage and Retrieval with Special Reference to the Geosciences, held in Adelaide, 2-6 October: P.J. Kennewell.

Seminar on Geostatistics and Ore Reserve Estimation conducted by P. Raftery at BMR, 19-20 October: P.J. Kennewell.

METALLIFEROUS SECTION

Head: W.B. Dallwitz

GEOLOGICAL INVESTIGATIONS IN NORTHERN TERRITORY AND ANTARCTICA

Supervising Geologist: D.B. Dow to September, D.H. Blake (from October)

ARUNTA PROJECT

by

R.D. Shaw, A.J. Stewart, A.P. Langworthy, L.A. Offe, R.G. Warren.

STAFF: R.D. Shaw, A.J. Stewart, L.A. Offe, A.P. Langworthy (to October), R.G. Warren, A.N. Yeates (3 weeks in field), and A.Y. Glikson (part time); B.E. Hobbs and C. Mawer (Monash University) are associated with the project.

The objectives of the Arunta Project are to obtain, study, and make available basic geological and economic mineral data on the Arunta Block in central Australia so as to provide a framework for the investigation of the region's mineral resources.

The chief results of the year's work are:

1. The achievement of substantial progress in map production (see below).
2. A major advance in lithological correlation between units mapped in the Alice Springs 1:250 000 Sheet area (Fig. M1 and Tables M1 and M2). This has led to further subdivision of the main regional lithological units recognised in the Arunta Block (Fig. M2).
3. Recognition of at least five, and possibly seven, metamorphic events in the Alice Springs 1:250 000 Sheet area (Table M3).
4. Publication of a paper on 'The Mordor Complex - a highly differentiated potassic intrusion with kimberlitic affinities in central Australia'. Contributions to Mineralogy and Petrology, 67, 51-62, 1978.
5. Completion of the data Record on the 1:100 000-scale mapping in the Alice Springs 1:250 000 Sheet area. This Record awaits editing.

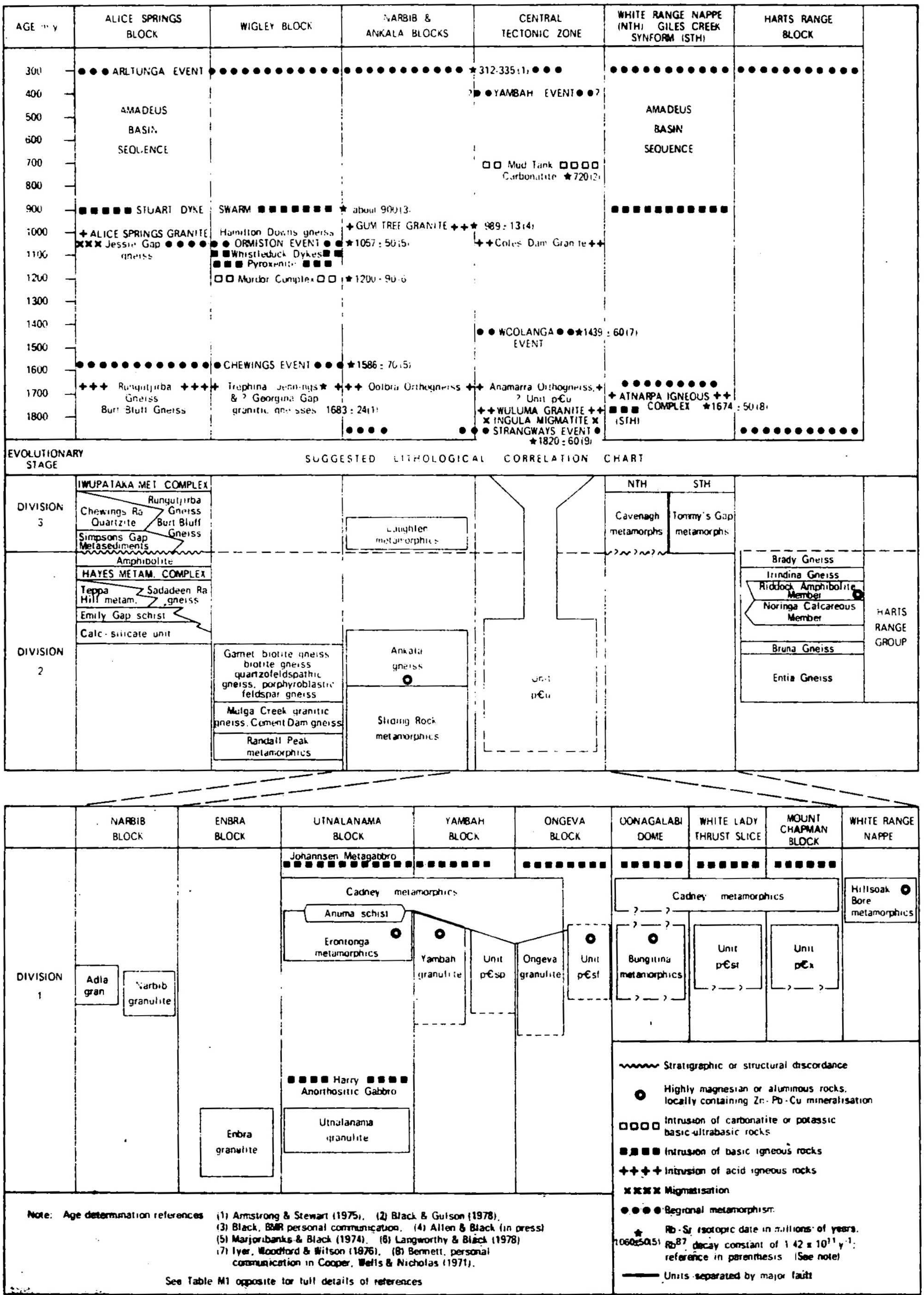


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Fig. M1 Suggested correlation of events and lithological units; Arunta Block; Alice Springs 1:250000 Sheet area.

TABLE M1. LITERATURE REFERRED TO IN FIGURE M1

ALLEN, A.P., & BLACK, L.P., in prep. - The polyphase deformational history of the Harry Creek Deformed Zone, southeastern Strangways Range, N.T., a retrograde schist zone in the Arunta Block.

ARMSTRONG, R.L., & STEWART, A.J., 1975 - Rubidium-strontium dates and extraneous argon in the Arltunga Nappe Complex, Northern Territory. Journal of the Geological Society of Australia, 22, 103-115.

BLACK, L.P., & GULSON, B.L., 1978 - The age of the Mud Tank Carbonatite, Strangways Range, Northern Territory. BMR Journal of Australian Geology & Geophysics, 3(3), 227-232.

COOPER, J.A., WELLS, A.T., & NICHOLAS, T., 1971 - Dating of glauconite from the Ngalia Basin, Northern Territory, Australia. Journal of the Geological Society of Australia, 18, 97-106.

IYER, S.S., WOODFORD, P.J., & WILSON, A.F., 1976 - Rb-Sr isotopic studies of a polymetamorphic granulite terrain, Strangways Range, central Australia. Lithos 9, 211-224.

LANGWORTHY, A.P., & BLACK, L.P., 1978 - The Mordor Complex: a highly differentiated potassic intrusion with kimberlitic affinities in Central Australia. Contributions to Mineralogy and Petrology, 67, 51-62.

MARJORIBANKS, R.W., & BLACK, L.P., 1974 - Geology and geochronology at the Arunta Complex, north of Ormiston Gorge, central Australia. Journal of the Geological Society of Australia, 21, 291-300.

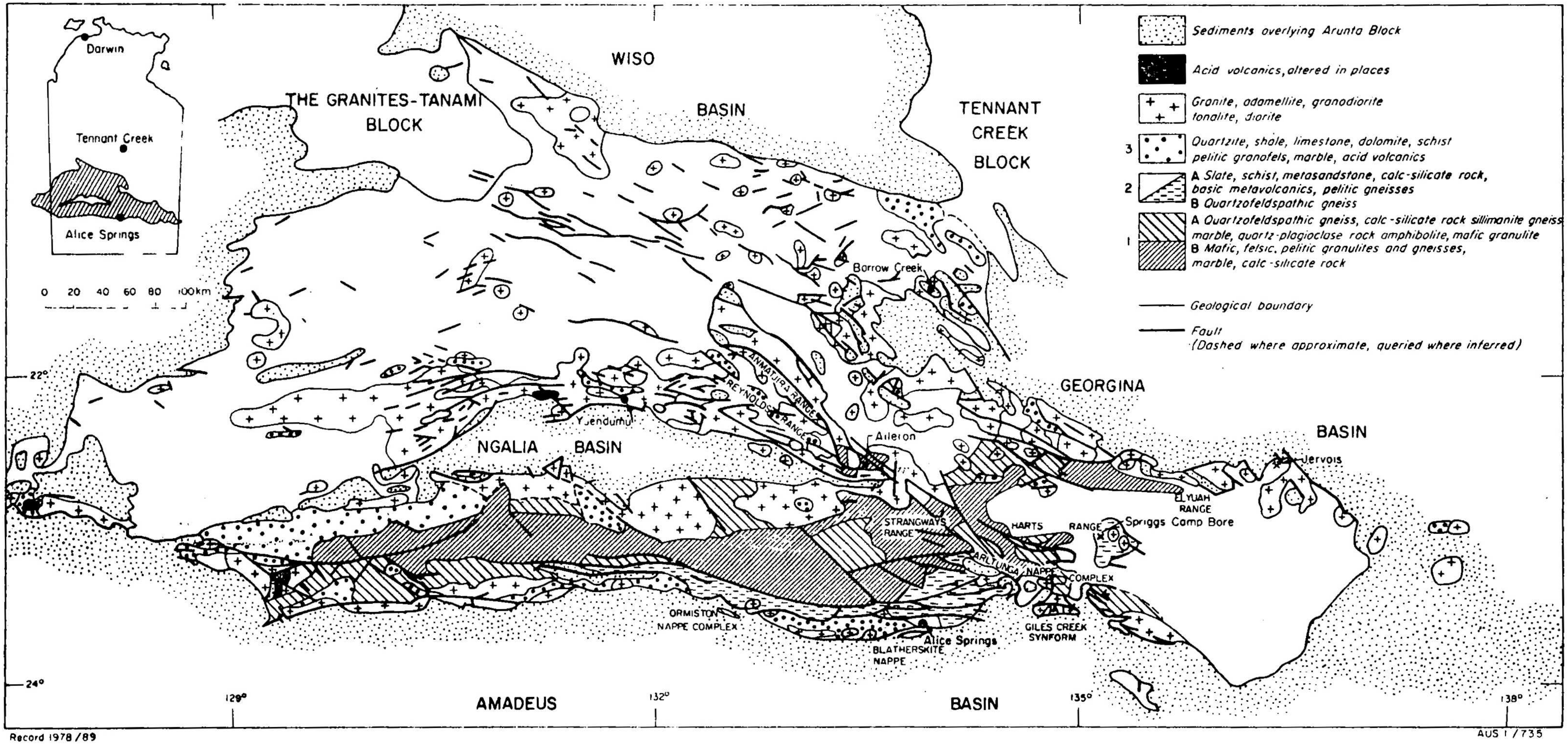

Fig M2 Generalised geological map of Arunta Block, showing major 'stratigraphic' subdivisions (1-3) and granite

TABLE M2. SUMMARY OF MAIN LITHOLOGICAL ASSOCIATIONS, ARUNTA BLOCK, ALICE SPRINGS 1:250 000 SHEET AREA

Evolutionary Stage	Mapped Units	Characteristic rock types
Division 3	Laughlen metamorphics, Cavenagh metamorphics, Iwupataka Metamorphic Complex, and possibly Tommy's Gap metamorphics.	Metamorphosed quartzose sandstone, arkosic sandstone, calcareous marl, and limestone: Tommy's Gap metamorphics are thought to be derived mainly from basic to intermediate igneous rocks.
Division 2	Hayes Complex, Brady Gneiss, Irindina Gneiss.	Schistose, garnet-bearing biotite-rich gneiss, biotite-bearing granitic gneiss, amphibolite, quartz-rich gneiss, calc-silicate rocks, and marble.
	Ankala gneiss, Sliding Rock metamorphics, Bruna Gneiss, Entia Gneiss, units of Wigley Block, and possibly Unit pЄu.	Granitic to granodioritic rocks forming layered sequences.
Division 1	Cadney metamorphics, Hill-soak Bore metamorphics, Anuma schist, and Erontonga metamorphics.	Dominantly calc-silicate rock, cordierite quartzite, sillimanite, gneiss, and other metasediments.
	Units pЄx, pЄst, pЄsf, and pЄsp; Ongeva, Yambah, Narbib and Adla granulites, and Bungitina metamorphics.	Dominantly felsic and mafic granulite.
	Harry Anorthositic Gabbro, Utnalanama granulite, Enbra granulite.	Dominantly rocks of basic to intermediate composition.

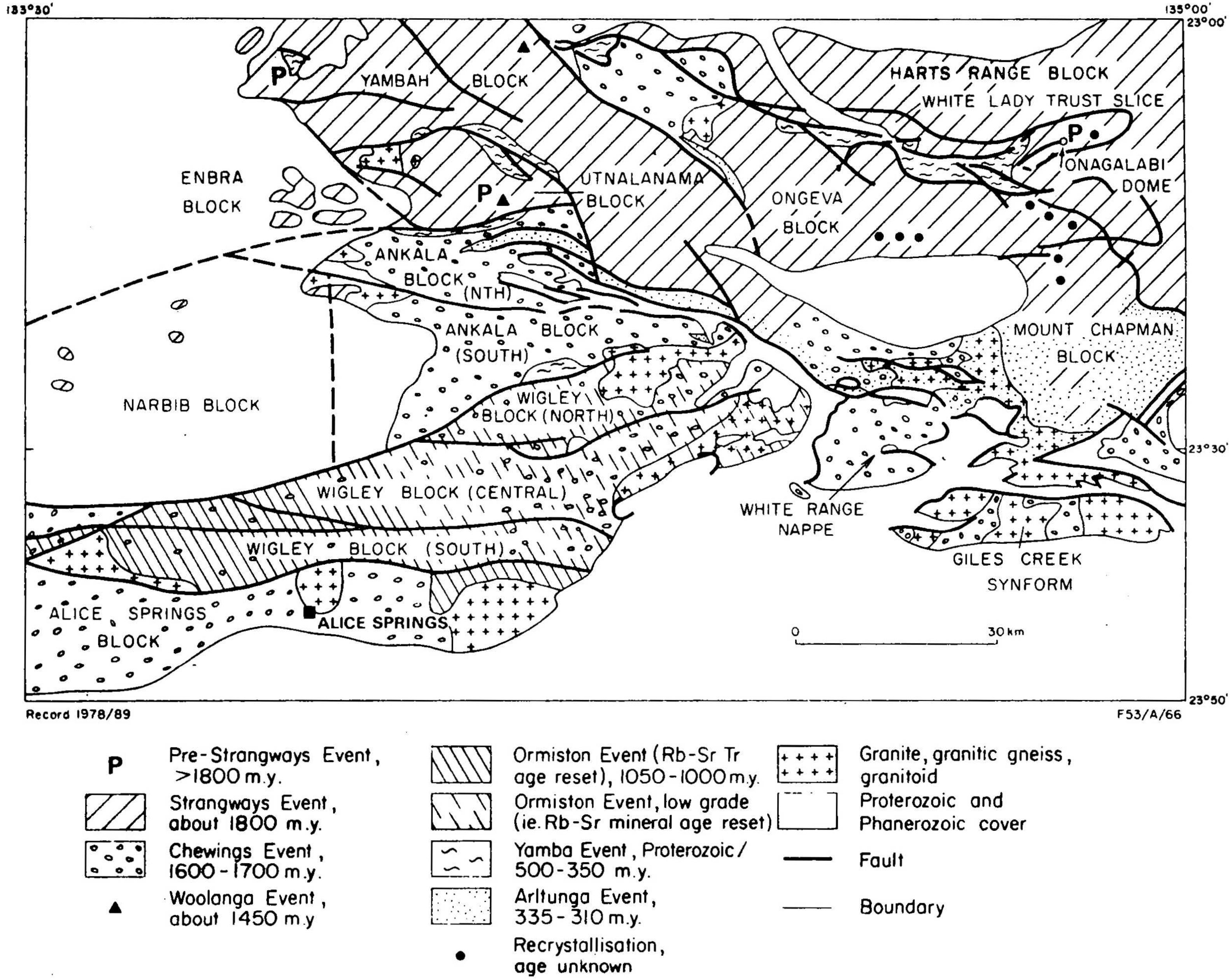

Fig. M3 Interpreted metamorphic events, southeastern Arunta Block; Alice Springs 1:250 000 Sheet area

TABLE M3. METAMORPHIC EVENTS, ALICE SPRINGS 1:250 000 SHEET AREA

METAMORPHIC EVENT	AGE* (M.Y.)	CHARACTERISTIC TEXTURE	TYPICAL GRADE	REFERENCE AREA
Pre-Strangways (P-St) (identification tentative)	Greater than 1820	Highly elongate grain shapes or relict, strained grains	UNCERTAIN	Yambah and phlogopite mine areas, YAMBAH BLOCK.
Strangways Event (St)	about 1800	Granuloblastic texture	GRANULITE	Yambah area, YAMBAH BLOCK
Chewings Event (Ch)	About 1600, possibly extending to 1650 - 1700	Weakly layered and lineated	LOW - PRESSURE ALMANDINE AMPHIBOLITE FACIES	Chewings Range area, HERMANNSBURG 1:250 000 Sheet area
Woolanga Event (Wo) (limited extent)	About 1450	Grain boundary alteration of main minerals (such as spinel to sapphirine or hogbomite)	GRANULITE FACIES	Woolanga Bore area, YAMBAH BLOCK
Ormiston Event (Or)	1050-1000	Recrystallisation and the formation of migmatite	AMPHIBOLITE FACIES	Ormiston area, HERMANNSBURG 1:250 000 Sheet area
Yambah Event (Ya) (identification tentative)	Probably 500 - 350; may be much older	Highly schistose	AMPHIBOLITE FACIES (Kyanite and staurolite typically present)	Yambah schist zone, YAMBAH BLOCK
Arltunga Event (Ar)	335 - 310	Highly schistose	GREENSCHIST FACIES	South of Claraville, WHITE RANGE NAPPE

*A Rb^{87} decay constant of $1.42 \times 10^{-11} y^{-1}$ has been used for this table.

DATA PRESENTATION (R.D. Shaw, A.P. Langworthy, A.J. Stewart, L.A. Offe)
ALICE SPRINGS 1:250 000 SHEET AREA

Generalisation of the six 1:100 000 sheets is complete, and the face of the map is being prepared for drafting. Mappable rock units are grouped into three informal regional divisions based on similarity of lithological associations (Table M2). Lithological correlation of units between individual structural blocks is given in Figure M1. The metamorphic events recognised in the Alice Springs 1:250 000 sheet area and their interpreted distribution are shown in Figure M3. Each event has been assigned a name and a reference area (Table M3), chosen to correspond to an area where an age determination has been carried out. Granite intrusion has occurred during the later stages of three of the metamorphic events. Petrological study of one of these intrusions, the Atnarpa Igneous Complex, which ranges from diorite to aplite, indicates that it is a consanguineous suite of differentiated calc-alkaline rocks.

Burt-Laughlen 1:100 000 Sheet areas: The combined Burt-Laughlen 1st edition map is completed and ready for drafting. The explanatory notes are in preparation.
Alice Springs 1:100 000 Sheet area: The preliminary edition was issued in late 1977. A revised legend has been prepared, and corrections to the face of the map have been completed for the 1st edition map.
Undoolya 1:100 000 Sheet area: Drafting of the preliminary edition was completed, and the map is now with the printer.
Fergusson Range 1:100 000 Sheet area: Drafting of the preliminary edition was completed, and the map is being corrected before going to the printer.
Riddoch 1:100 000 Sheet area: Photo-compilation and reduction are complete, and drafting of the map is in progress.

HERMANNSBURG 1:250 000 Sheet area

Macdonnell Ranges 1:100 000 Sheet area: C. Mawer (Ph.D. student, Monash University) completed four months' independent field work as part of a structural study of the region. This work completes Monash University's contribution to the cooperative project. Photo-overlays are being prepared for compilation.

Anburla and Narwietooma 1:100 000 Sheet areas: Overlays are awaiting drafting. Thin sections have been examined. Samples are being prepared for geochemical analysis.

MOUNT PEAKE 1:250 000 SHEET AREA:

The first edition of the map and accompanying explanatory notes were distributed. A new solid geology (pre-Cainozoic) map has since been prepared using aeromagnetic data (flown by the Geophysical Branch in 1976). This map (Figs M4, M5) shows more granite and less Lander Rock Beds than shown on the first edition maps, a much larger extent of the Amesbury Quartzite Member of the Central Mount Stuart Formation, and numerous major faults trending northwest.

NAPPERBY 1:250 000 SHEET AREA:

In preparation for a second edition, the geology of the Reynolds Range, Denison, Tea Tree, and Aileron 1:100 000 Sheet areas was generalised, and a solid geology (pre-Cainozoic) map of the entire Sheet area, using aeromagnetic data obtained in 1976 by the Geophysical Branch, was prepared (Figs M6, M7). Significant advances on previous knowledge include recognition of: (1) numerous masses interpreted as mixed felsic and mafic granulites in the southeast quadrant, (2) a possible mafic granulite body of considerable extent in the southwest, (3) considerable subsurface extent of an ultrabasic body in the southeast, known from a small surface showing, (4) several major latitudinal faults in the southern part of the Sheet area with associated quartz-hematite concentrations. In addition, a revision of the outline of the northern margin of the Ngalia Basin is shown.

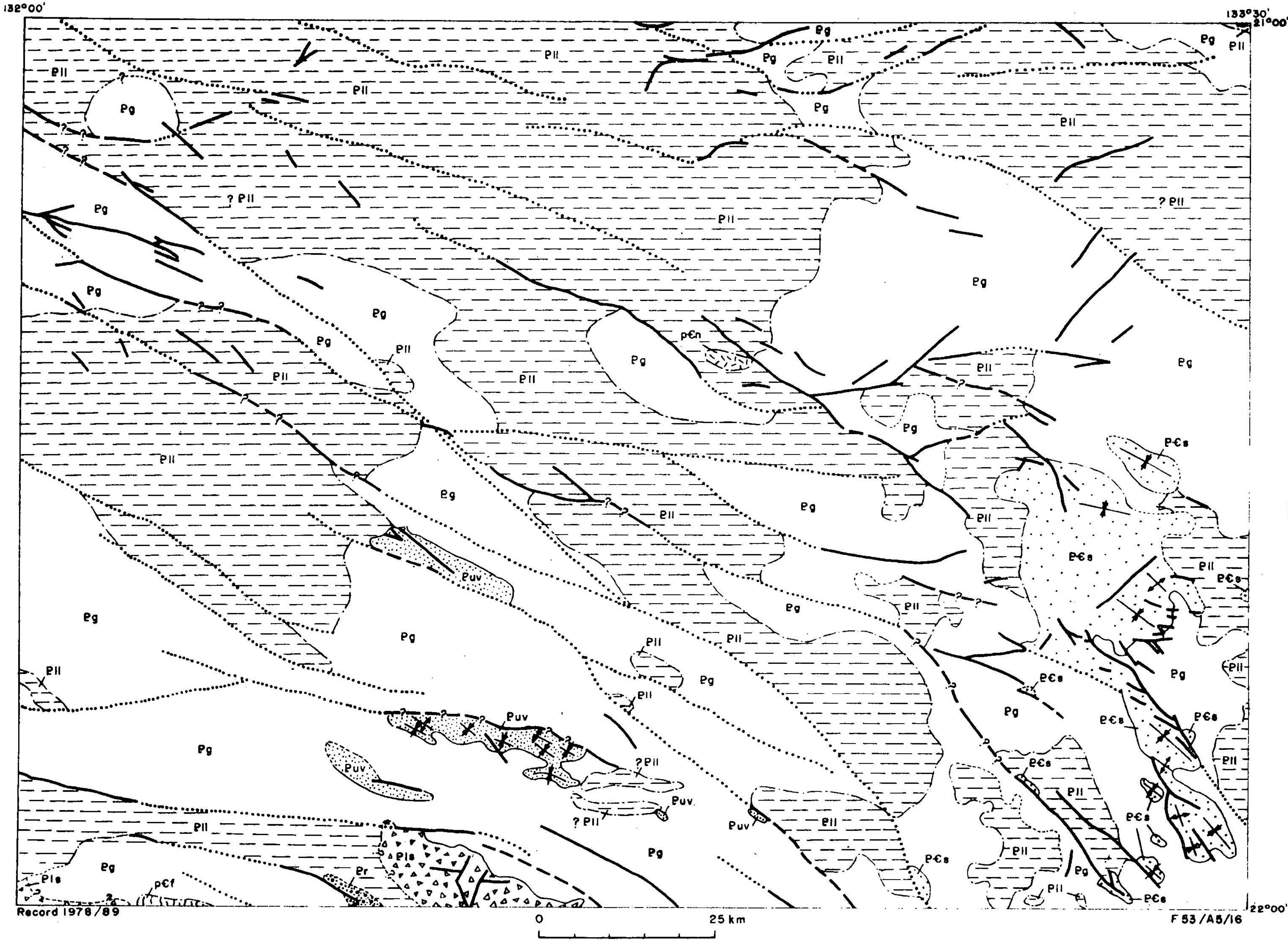

Fig. M4 Solid geology, Mount Peake 1:250 000 Sheet area
Geophysical interpretation by A.J. Stewart

Era	Unit	Symbol	Description
PALAEOZOIC	CENTRAL MOUNT STUART FORMATION	P€s	*Feldspathic sandstone, quartzite*
PROTEROZOIC	VAUGHAN SPRINGS QUARTZITE	Puv	*Quartzite, conglomerate*
		Pg	*Granite, porphyritic granite*
	REYNOLDS RANGE GROUP	Pr	*Quartzite, shale*
	MOUNT STAFFORD BEDS	Pls	*Hornfels*
	LANDER ROCK BEDS	Pll	*Schist, metasandstone, biotite gneiss*
PRECAMBRIAN		p€f	*Felsic paragneiss*
		p€n	*Strongly magnetic body*

- *Geological boundary, accurate*
- *Geological boundary, approximate*
- *Magnetic zone boundary*
- *Fault, dashed where approximate, queried where inferred*
- *Fault interpreted by magnetic data*
- *Antiform*
- *Synform*

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Fig. M5 Reference, Mount Peake solid geology map (Fig. M4)

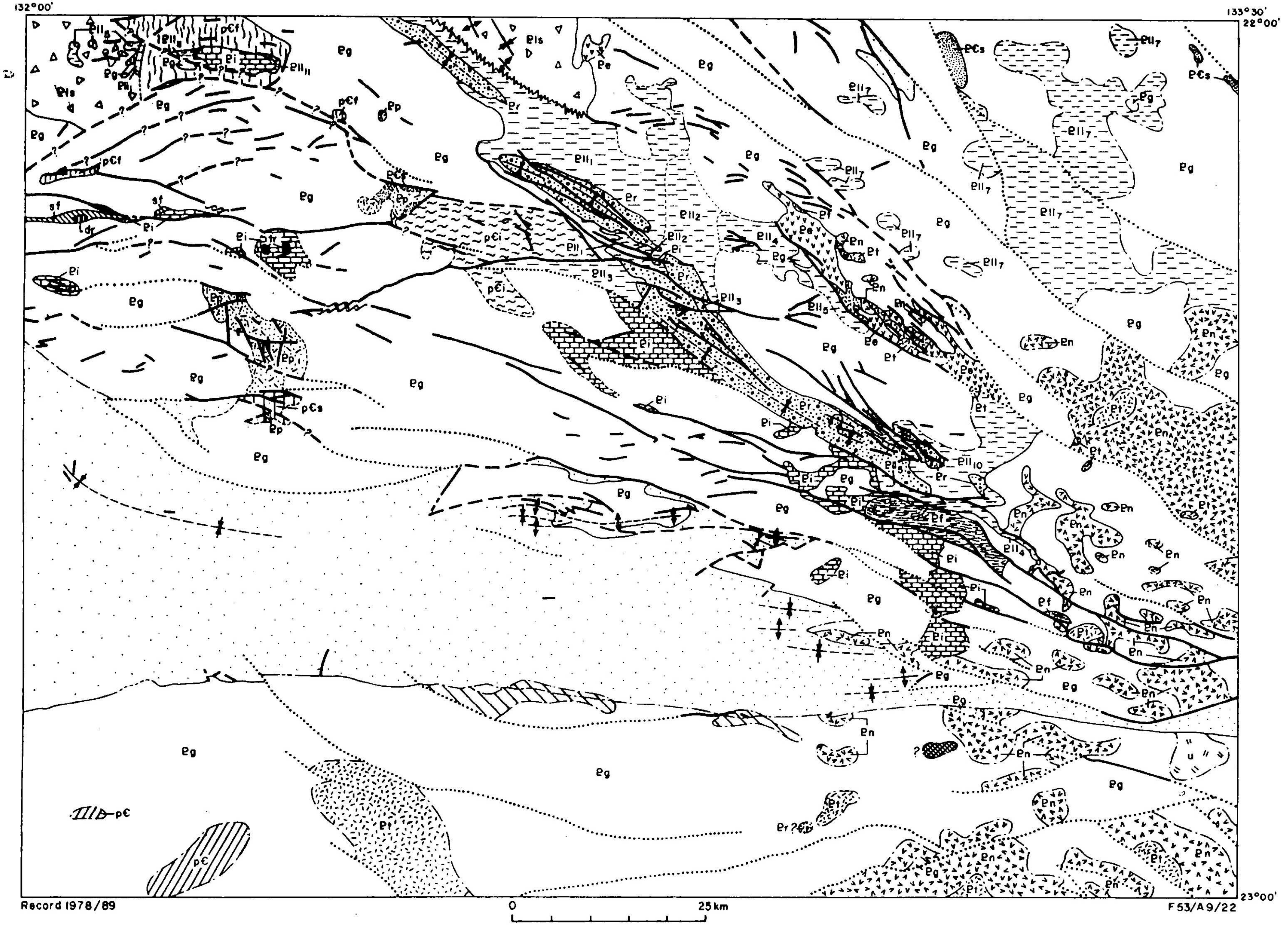

Fig.M6 Solid geology, Napperby 1:250 000 Sheet area

Geophysical interpretation by A.J. Stewart

PALAEOZOIC — CAMBRIAN

- €s — **Central Mount Stuart Formation**. *Red-brown sandstone, siltstone, tillite*
- *Sediments of Ngalia Basin*

PROTEROZOIC

- tr — *Troctolite*
- u — *Ultramafic rock*
- Pp — *Porphyry*
- Pg — *Granite, granitic gneiss, gneissic granite*
- dr — *Diorite*
- Pr — **Reynolds Range Group**. *Quartzite, shale grading to schist, paragneiss, pelitic granulite in S.W. Includes porphyry sills*
- Pls — **Mount Stafford Beds**. *Cordierite hornfels, pelitic granulite*
- Pll — **Lander Rock Beds**.
  - Pl_1 — *Micaceous sandstone, siltstone, sericite slate*
  - Pl_2 — *Micaceous sandstone, cleaved siltstone, andalusite slate*
  - Pl_3 — *Schist, phyllite, andalusite hornfels*
  - Pl_4 — *Biotite-muscovite schist, metasandstone*
  - Pl_6 — *Sillimanite-biotite-muscovite schist*
  - Pl_7 — *Biotite-feldspar-quartz gneiss*
  - Pl_{10} — *Pelitic granulite*
  - Pl_{11} — *Pebbly sandstone*
- sf — *Orthoschist with feldspar augen*
- Pi — **Wickstead Creek Beds**. *Calc-silicate rock, quartzite*
- Pf — **Mount Freeling Beds**. *Quartz-rich metasediment, schist*
- Pn — *Felsic and mafic granulites*
- Pe — **Weldon Granulite**. *Pelitic granulite*
- Pl — *Mafic granulite, subordinate felsic granulite*

PRECAMBRIAN

- p€f — *Felsic paragneiss*
- p€ — *Muscovite-biotite gneiss*
- p€s — *Muscovite schist, slate, metasandstone*
- p€ — *Undivided metamorphic rock*

- *Zone of quartz-hematite veins*
- *Quartz*
- *Geological boundary, dashed where approximate*
- *Fault, dashed where approximate ; queried where inferred*
- *Magnetic zone boundary*
- *Fault indicated by magnetic data*
- *Facies change*
- *Shear zone*
- *Antiform*
- *Synform, overturned*

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Fig.M7 Reference, Napperby solid geology map (Fig.6)

Denison and Aileron 1:100 000 Sheet area: Compilation is complete, and drafting of the preliminary editions is in progress.

Reynolds Range 1:100 000 Sheet area: Corrections began to Reynolds Range and adjoining parts of Mount Peake, Tea Tree, Aileron, and Napperby 1:100 000 Sheets that include well-exposed Arunta rocks, as a first step towards preparation of a colour edition map of those areas.

FIELD ACTIVITIES (R.D. Shaw, R.G. Warren)

Shaw spent six weeks and Warren four weeks in the field with the aims of (1) clarifying lithological pre-metamorphic correlations of the host formations to the Oonagalabi-type Zn-Pb-Cu deposits, (2) determining the pre-metamorphic nature of sequences containing Oonagalabi-type lodes, and (3) re-examining problem areas to assist compilation of the Alice Springs 2nd edition 1:250 000 map.

Shaw and A.T. Wells (Sedimentary Section) acted as guides for a 5-day tour of the Upper Proterozoic and Cambrian sedimentary succession in the Amadeus Basin by a group of seven geologists from the People's Republic of China.

Zn-Pb-Cu OCCURRENCES

Zn-Pb-Cu occurrences of the Oonagalabi type in the Alice Springs 1:250 000 Sheet area occur in lenses, up to 1000 m long, of anthophyllite or gedrite rock (with relict cordierite-spinel-orthopyroxene granulite), calc-silicate rock and/or marble, and less commonly layered magnetite quartzite or magnetite-grunerite rocks (Fig. M1). Total metal (Cu, Pb, and Zn) content rarely exceeds two percent. Cordierite- and/or garnet-bearing feldspathic quartzite typically forms country rock to the mineralised horizons. Amphibolites are commonly present in the enclosing sequence, and less commonly well-layered metapelitic rocks. The mineralised horizons are interpreted as volcanogenic deposits in which the anthophyllite (s.l.) rocks are metamorphosed chloritic products of explosive submarine volcanic activity.

SPECIMENS FOR BMR MUSEUM (collected by R.G. Warren and D.H. McColl)

In the course of a three-weeks' collecting trip idioblastic kornerupine and sapphirine were obtained from a lens of albite-biotite rock near the top of the lower part of the Strangways Metamorphic Complex near Old Station Well (Alice Springs 1:250 000 Sheet area). Kornerupine was also collected from the Pine Hill Formation, 21 km northwest of Aileron, and sapphirine-spinel and diaspore-phlogopite rocks from 1 km north of Aileron (Napperby 1:250 000 Sheet area). Epidote, albite, rutile, and sphene crystals were obtained from tension joints in amphibolite of the Irindina Gneiss in the Spriggs Camp district (Illogwa Creek 1:250 000 Sheet area).

MISCELLANEOUS ACTIVITIES

Shaw co-authored a paper with A.J. Mutton (Geophysical Branch) entitled 'Physical property measurements as an aid to magnetic interpretation in basement terrains' which was given at a Symposium on Applied Magnetic Interpretation at the University of Sydney in August.

Stewart participated in a 5-day excursion in the Cobar area organised by the Geological Survey of New South Wales in November, attended the symposium on Applied Magnetic Interpretation at Sydney University in August, and gave a lecture on 'Structural Geology of the Arunta Block' to the Hunter Valley Branch of the Geological Society of Australia in October.

Offe attended a one-week Australian Mineral Foundation course entitled 'Structural Geology and Mineral Exploration' in August.

Warren gave three lectures to the third-year geological class at James Cook University, Townsville, on the Precambrian geology of Australia.

DARWIN OFFICE

by

C.E. Prichard

STAFF: C.E. Prichard, P.H. Fuchs, P.R. Lachlan, N.A. Ashmore, A.J. Neilsen

There was no change in staff during the year, but the two drawing office positions will be transferred to Canberra in 1979.

The geological, geophysical, and drilling parties operating in the area left vehicles and stores at the Darwin Base at the end of the 1977 field season. Two mechanics from the Drilling Group spent a month in Darwin servicing and repairing twenty three vehicles and fourteen trailers in readiness for the 1978 season.

Drafting of the Oenpelli, Howship, and Jim Jim 1:100 000 preliminary maps continued, and final corrections were made to the Kapalga 1:100 000 preliminary map.

General support and assistance has been available to the Pine Creek Party and the Drill Party during 1978, and to visiting officers and other parties passing through the area. These include the Airborne Party, Regional Magnetic Party, the Strangways Party, and the Palaeomagnetic Party. Entry permits into Wildlife Sanctuaries were arranged for the Palaeomagnetic Party and for M.J. Jackson and M.D. Muir.

Services to the general public, schools, and the mining industry increased compared with previous years. Map and Publication sales averaged 90 a month; many of these involved simple discussion and explanation of the maps. Prospectors and mining company geologists made increased use of reference services. Earth-science classes from three local high schools visited the office, and were shown the functions performed. A talk 'Mining and the Environment' was given to one school, and the Senior Geologist took part in an Earth Science Workshop arranged by the Science Teachers Association.

Magnetic susceptibility and specific gravity were determined on some hundreds of samples of core held in Darwin by CRAE, Geopeko, BMR, and Mines Branch at the request of D.H. Tucker (Geophysical Branch).

MTN Seismic Station was maintained in continuous operation throughout the year. Some record was lost because of power failures in the Manton area.

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; M.J. Roarty and G.C. Lau (N.T. Geological Survey); T.W. Brown (draftsman).

The objectives of this project are:

1. To gain a more detailed understanding of the geology of the Pine Creek Geosyncline.
2. To indicate the controls and distribution of uranium and other mineralisation in the geosyncline.
3. To prepare and publish a new series of 1:100 000-scale geological maps, and to revise the 1:250 000-scale geological maps of the region.

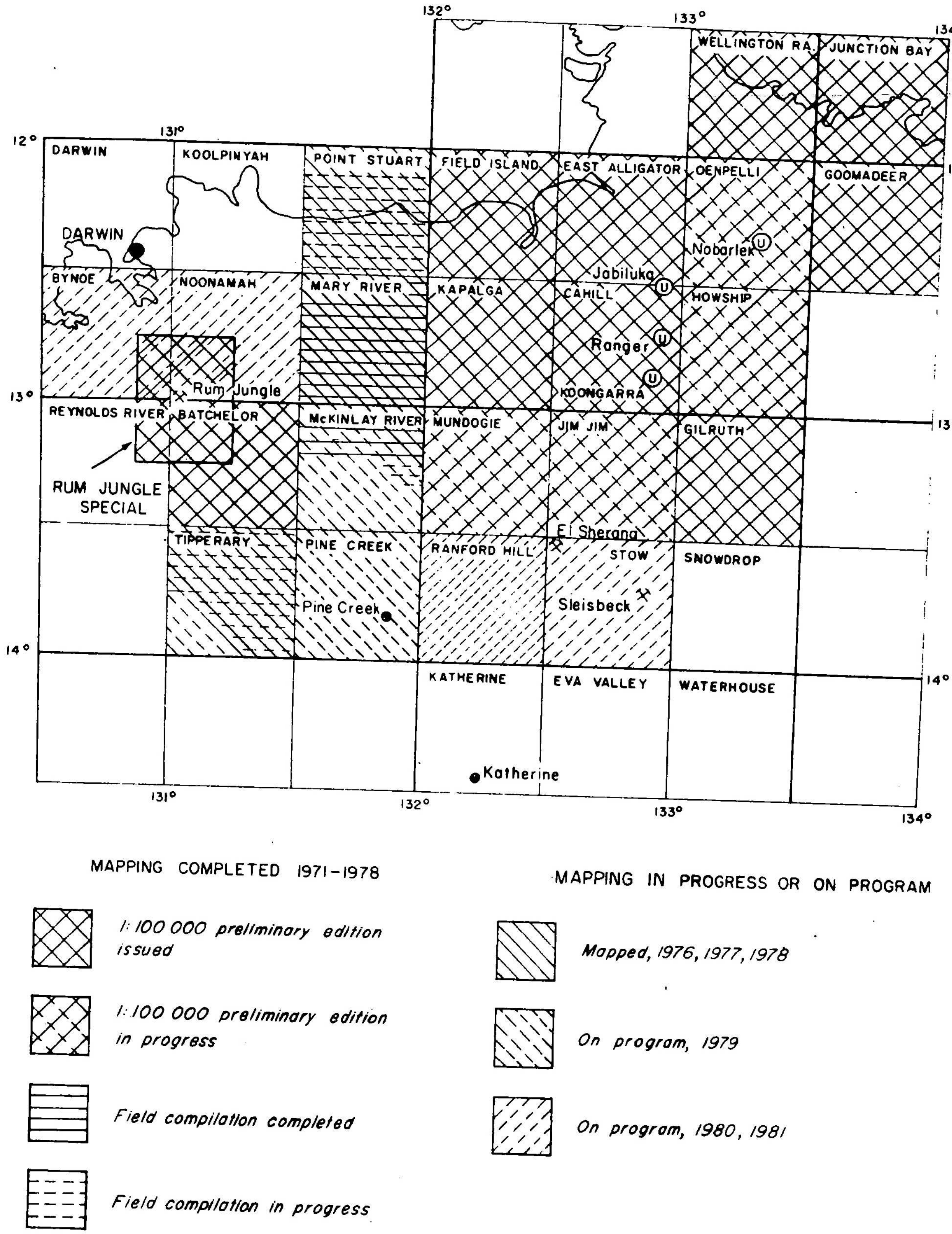
The Pine Creek Geological Party is one part of a multidisciplinary project studying many aspects of the geosyncline. Geophysicists involved are: D.H. Tucker, I.G. Hone, A.J. Mutton, N. Sampath, D.C. Stuart, P.G. Wilkes. Results of research by other groups within the project are reported elsewhere in this report and in the annual summaries of other Branches of B.M.R.

To date sixteen 1:100 000 Sheet areas have been covered by semi-detailed field investigations; nine preliminary standard-series and one preliminary special-series 1:100 000 maps have been published, and four more standard-series preliminary maps are at an advanced stage. Field compilation sheets, mainly at 1:25 000- or 1:50 000-scale, are available for all areas investigated to date. During 1978 emphasis has been on petrological studies of rocks from the Mundogie Sheet area, field work in the McKinlay River, Mary River, and Point Stuart Sheet areas, and establishing correlations between the Rum Jungle, Burnside, Mundogie, and Alligator Rivers areas. A solid geology map of the Pine Creek Geosyncline at 1:500 000 scale was compiled for the International Uranium Symposium on the Pine Creek Geosyncline to be held in

June 1979, and this map incorporates the newly defined stratigraphy. Field work in the Tipperary Sheet area continued only spasmodically, owing to other commitments on the part of G.C. Lau. Work next year will concentrate on contributions for the June symposium, and fieldwork will be in the McKinlay River, Pine Creek, and Noonamah Sheet areas, together with regional reconnaissance in the Litchfield Block. With current manpower the geological investigations will be completed in about 7 years.

REPORTING AND PROGRESS OF MAP PRODUCTION, by R.S. Needham

Progress of map production is shown in the frontispiece and in Fig. M8. The Kapalga, Batchelor, and Rum Jungle Special 1:100 000 preliminary maps were issued during the year. Final drafting of the Jim Jim, Howship, Oenpelli, and Mundogie preliminary maps is in progress. The second edition Alligator River 1:250 000 map is being compiled, and explanatory notes are being prepared. A Bulletin is being prepared to accompany the 1:100 000 maps of the Alligator Rivers Uranium Field. Records describing the 1974-6 drilling results in the Kapalga area and BMR's involvement in the Pine Creek Geosyncline between 1949 and 1977 were issued. Records describing results of studies in the Alligator Rivers area from 1973-6 and in the Batchelor Sheet area, and presenting preliminary data from field work in the Mundogie Sheet area, were drafted and await editing. Papers describing the Oenpelli Dolerite, Zamu Dolerite, Lower Proterozoic tuff in the Pine Creek Geosyncline and its stratigraphic significance, and deformation structures in the Kombolgie Formation were published in various journals. Solid geology maps of the Pine Creek Geosyncline at 1:500 000 and 1:2 000 000 scales have been compiled, and will be printed for the International Uranium Symposium in June 1979. At the 1978 BMR Symposium, Crick presented a paper on Pine Creek Geosyncline stratigraphy, and Needham participated in a panel discussion on 1:100 000-scale geological mapping of Precambrian terrains in northern and central Australia.



Record 1978/89

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Fig. M8 Progress of geological mapping and index to 1:100 000 Sheet areas, Pine Creek Geosyncline Project

MUNDOGIE SHEET AREA, by R.S. Needham

The draft data Record contains 1:25 000-scale field compilation sheets covering the area. Petrographic work has refined the rock-type descriptions of the various units, and has precipitated a review of the relationships of some units. Solid geology is shown in Fig. M9.

The Masson Formation contains calcareous and volcanic greywackes. The volcanic greywackes lie along the axes of northwest-trending synclines, and are therefore apparently near the top of the formation - possibly they belong to the Stag Creek Volcanics which overlie the Masson Formation. The most westerly exposure of Stag Creek Volcanics is 3 km north of the Namoona lead prospect, where the formation is host to a small, previously unrecorded, copper prospect. The main rock types in the unit are basic volcanic breccia, hawaiite, tuff, tuffaceous shale, and tuffaceous greywacke.

Two drill holes put down in late 1977 to determine the source of magnetic and gravity patterns on the western edge of the Barramundie Creek plains intersected tuffaceous phyllite with carbonate bands and fine, spotted meta-volcanics and fine quartzite interpreted as Stag Creek Volcanics, indicating that the underlying poorly exposed rocks of the Barramundie plains area are equivalents of the Masson Formation. More drilling in 1978 on the eastern side of the plain near the abandoned Barramundie homestead intersected fine grey carbonate rocks and chlorite schist. Chlorite is rare in this area in units other than Stag Creek Volcanics, so the inference is that the Barramundie plains area is a dome, with Masson Formation (previously described as subunit Elp_1 of the Mount Partridge Formation) surrounded by Stag Creek Volcanics. The surrounding Mundogie Sandstone and Mount Partridge Formations appear to be stratigraphic equivalents. There is no significant difference between the lithologies of these two units; therefore the name Mundogie Sandstone is elevated to formation status and extended to cover sandstone, quartzite, and conglomerate of the Mundogie Sandstone Member and subunits Elp_2 and Elp_4 of the Mount Partridge Formation.

A siltstone and shale unit previously ascribed mainly to the Masson Formation appears to conformably overlie the Mundogie Sandstone (and the Mount Hooper Sandstone farther north in the Kapalga Sheet area). It crops

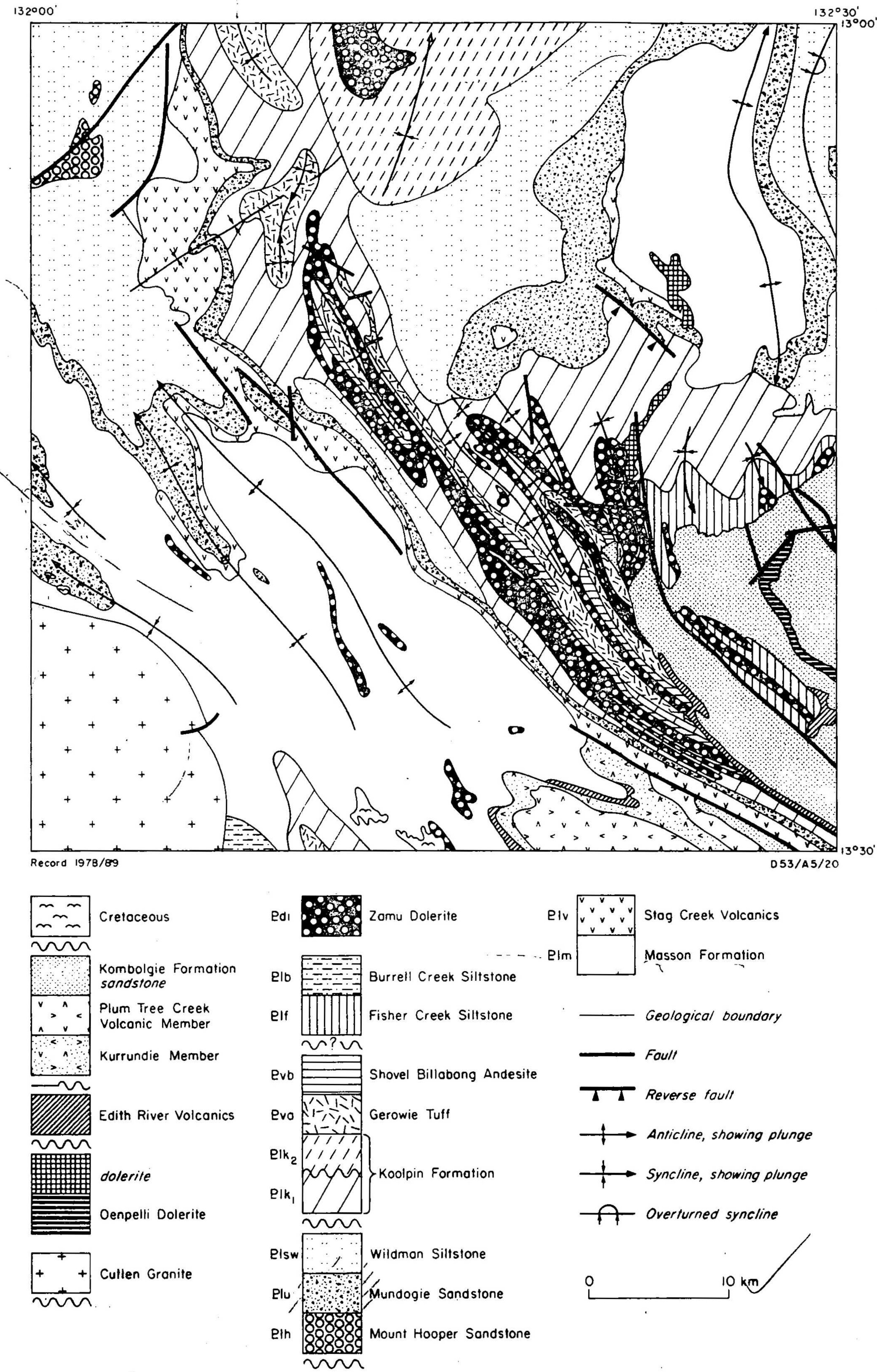

Fig. M.9 Mundogie 1:100 000 Sheet area, interpreted solid geology out mostly north and west of the headwaters of Stove Creek and in the Buffalo Creek floodplain, and extends through Spring Peak into the core of an overturned anticline in the Mount Partridge Range, where it was previously described as subunit Ėlp$_3$ of the Mount Partridge Formation. This unit is commonly prominently colour-banded where weathered, and has been named the Wildman Siltstone.

The upper part of the Koolpin Formation, which forms a wide north-plunging syncline in the north of the Sheet area, has been renamed the Kapalga Formation, as it is unconformable over the remainder of the unit. It contains black shale and iron-rich rocks with chert bands, but carbonate rocks and banded iron formation similar to those in the lower Koolpin Formation are absent. Argillite, tuff, and tuffaceous greywacke interbedded with the Koolpin Formation sensu stricto, and previously called Gerowie Chert, are renamed Gerowie Tuff. In close association with the Gerowie Tuff are bodies up to 100 m thick of variolitic andesite (the Shovel Billabong Andesite) which are probably extrusives genetically associated with the tuff.

The Lower Proterozoic sedimentary and volcanic rocks are intruded by sills of olivine dolerite, quartz dolerite, and diorite and granophyre of the Zamu Dolerite. An intrusion of porphyritic lamprophyre exposed along the west bank of the South Alligator River for 12 km south of Shovel Billabong is possibly a related differentiate. Unlike the other Zamu Dolerite types, however, it has a distinctively higher (x3 to x4) radioactivity. Another quartz dolerite intrudes the Lower Proterozoic strata between 6 and 20 km northeast of Shovel Billabong. It is nowhere exposed, being represented by a thick, clayey weathering profile, but its presence has been confirmed by exploration-company drilling. Its sinuous and irregular shape in plan and lack of outcrop are markedly different from the regular, prominent, arcuate ridges of Oenpelli Dolerite, and it is probably younger.

The Mundogie Sheet area contains the Rockhole uranium mine and associated minor workings in black shale of the Koolpin Formation where it is in faulted contact with Kombolgie Formation sandstone. The Mundogie and Yemelba gold occurrences (alluvial and minor shallow workings) may be related to a concealed granite suggested by a prominent gravity low in the Spring Peak area. Several minor, previously unrecorded, lead prospects in Masson

Formation northwest of the Namoona prospect occur along a gossanous zone striking at a low angle to bedding. A previously unrecorded small copper show in Stag Creek Volcanics occurs 3 km north of Namoona.

MARY RIVER, POINT STUART, and McKINLAY RIVER 1:100 000 SHEET AREAS, by P.G. Stuart-Smith, M.J. Roarty, and D.A. Wallace

Field research during 1978 covered all of the Mary River and Point Stuart Sheet areas, and the northern 40 percent of the McKinlay River Sheet area. The generalised geology of these areas is shown in Figure M10.

Most of the Point Stuart Sheet area and the northern parts of the Mary River Sheet area are covered by Cainozoic lateritic sand, minor Cretaceous sandstone, and extensive Quaternary river and coastal floodplain deposits. The oldest rocks exposed are feldspathic, psammitic sediments of the Mount Hooper Sandstone, which crop out as domal inliers within Wildman Siltstone on the eastern margins of all three sheet areas and in the centre of the Mary River Sheet area. The Mount Hooper Sandstone and Wildman Siltstone were previously termed Mount Partridge Formation and Masson Formation, respectively.

The Wildman Siltstone, which conformably overlies the Mount Hooper Sandstone, consists of colour-banded siltstone, purplish red and creamy shale, minor fine- to medium-grained quartzite and quartz sandstone, and very minor carbonaceous shale. Chiastolite occurs in carbonaceous shale in the contact aureole of the Mount Bundey Granite. Asymmetrical ripple marks, load casts, and lenticular cross bedding are common sedimentary structures in sandstone, and probably indicate a shallow-water depositional environment. Pelitic units of the formation are well exposed only in road cuttings along the Arnhem Highway; they commonly exhibit rounded tight folds with well developed axial-plane cleavage.

Massive silicified dolomite and ferruginous silicified dolomite breccia crop out in the central and western parts of the Mary River Sheet area. As the contact with surrounding Wildman Siltstone is not exposed, their stratigraphic position is uncertain. They possibly represent a small basin of Koolpin Formation.

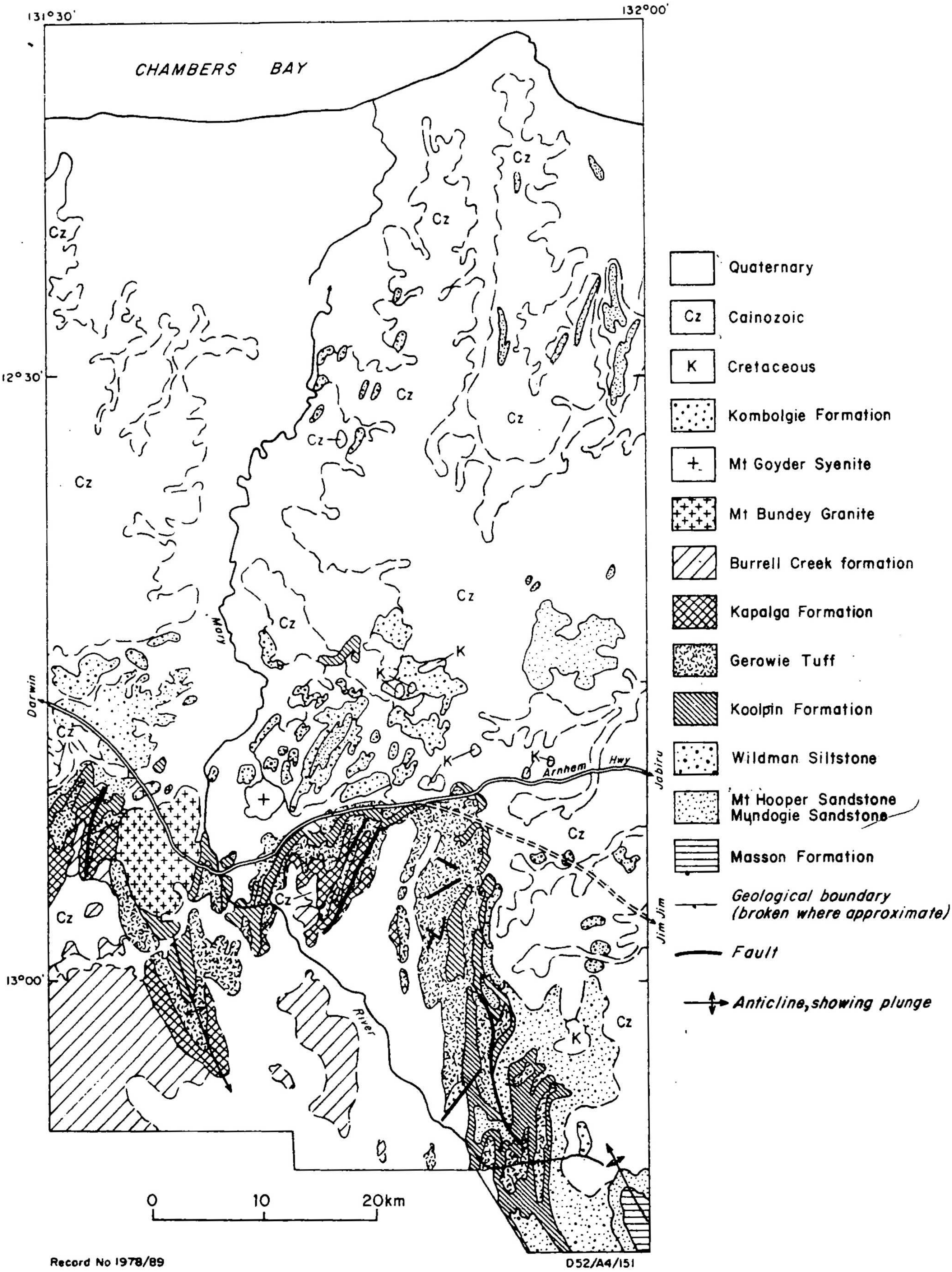

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Fig. M10 Generalised geology of the Mary River, Point Stuart and part of McKinlay River 1:100 000 Sheet areas.

The Koolpin Formation - previously termed Craig Creek Member of the Golden Dyke Formation in this area - is a continuous, unit of highly ferruginous purple and mauve siltstone about 200-300 m thick, in which chert bands and lenses become more prominent southwards; the unit has a distinct dark photo-tone, and unconformably overlies the Wildman Siltstone.

The Gerowie Tuff forms prominent continuous ridges covered with characteristically white cherty rubble, and consists of spotted green tuff (as in the Mundogie area), fine grey siliceous rocks (as in the Rum Jungle area), and possible crystalline flow rocks (to be determined by thin-section studies). The Koolpin Formation and Gerowie Tuff are clearly conformable and are interbedded in road cuttings near the Mary River bridge, where the best exposures of the two formations in the area are to be found.

The Gerowie Tuff is overlain by a conformable sequence of siltstone with black chert nodules, and a dark green rock of arkosic appearance which may represent a facies variant of the Kapalga Formation of the Mundogie/Kapalga Sheet areas, or may alternatively be Burrell Creek Formation. The Burrell Creek Formation forms low rubbly rises, and consists mostly of red and grey sandy micaceous siltstone, black fine siliceous sediments, and 'tombstone' greywacke.

The Koolpin to Burrell Creek sequence strikes east in the central Mary River Sheet area, and is folded about shallowly south-plunging axes; the regional trend swings sharply to the south in the southeast quarter of the Sheet area, and in this trend folding and faulting is complex: the Koolpin Formation, Gerowie Tuff, Wildman Siltstone, and Mundogie Sandstone are commonly in faulted juxtaposition along this belt.

Extremely weathered brown fine massive rocks previously mapped as dolerite intruding Wildman Siltstone northeast of the Mount Bundey Granite do not appear to be intrusives, as two holes drilled into them intersected pyritic carbonaceous shale and a massive pyritic chloritic carbonate rock of possible volcanic origin. Previously unrecorded unaltered fine dolerite intrudes Gerowie Tuff in the north of the McKinlay River Sheet area. Unusual magnetite-bearing dyke rocks, some nearly 100 percent biotite, others 50 per cent biotite/50 percent K-feldspar, intrude the sediments near the Mount Bundey Granite and the Mount Goyder Syenite, which themselves are rich in biotite.

CORRELATIONS WITH THE RUM JUNGLE AREA, by I.H. Crick

The Lower Proterozoic sequence in the Rum Jungle area, particularly the Golden Dyke Formation as subdivided by K. Johnson, has been re-examined with a view to firmly establishing correlations with the stratigraphic succession recently defined in the Mundogie and Mary River Sheet areas. It is hoped that the 1:100 000-scale Batchelor and Rum Jungle Special maps will be amended to portray the more recently defined stratigraphy. The subunits of the Golden Dyke Formation are to be named by use of the correlative Kapalga Formation, Koolpin Formation, Gerowie Tuff, and Masson Formation or Wildman Siltstone units (Fig. M11).

In the Noonamah Sheet area the Koolpin Formation (Johnson's Eld$_6$ or Craig Creek Member of the Golden Dyke Formation) is less than 100 m thick, and contains silicified carbonate breccia and oolites in a fine commonly ferruginous matrix, rare recrystallised chert, nodular ferruginous siltstone, and in places vuggy massive ironstone containing botryoidal hematite. It is overlain by chert-like rocks of the Gerowie Tuff, previously mapped as Eld$_7$ of the Golden Dyke Formation. These two formations can be traced from the Mary River Sheet area, through the Noonamah Sheet area, and into the north-eastern part of the Rum Jungle Special Sheet area. East and southeast of Batchelor the Gerowie Tuff overlies a more massive brecciated and commonly hematite-veined chert (silicified carbonate?), possibly of the Koolpin Formation. The Gerowie Tuff was previously mapped in places south-east of the Waterhouse Complex as Burrell Creek Formation.

Unconformably underlying the Koolpin Formation in the Noonamah Sheet area are poorly exposed siltstone and blocky quartz arenite of the Wildman Siltstone. These rocks are very similar to the Acacia Gap Tongue with which they are now correlated.

A calcareous amphibolite previously mapped as Eld$_7$ south-east of the Waterhouse Complex is absent in most places, and in one place is a very ferruginous chert and milky-quartz breccia belonging to the Depot Creek Sandstone Member. A strongly foliated amphibolite beneath the Koolpin Formation (Eld$_6$) 6 km south-east of Batchelor also crops out south of the Waterhouse Complex in probably the same stratigraphic position.

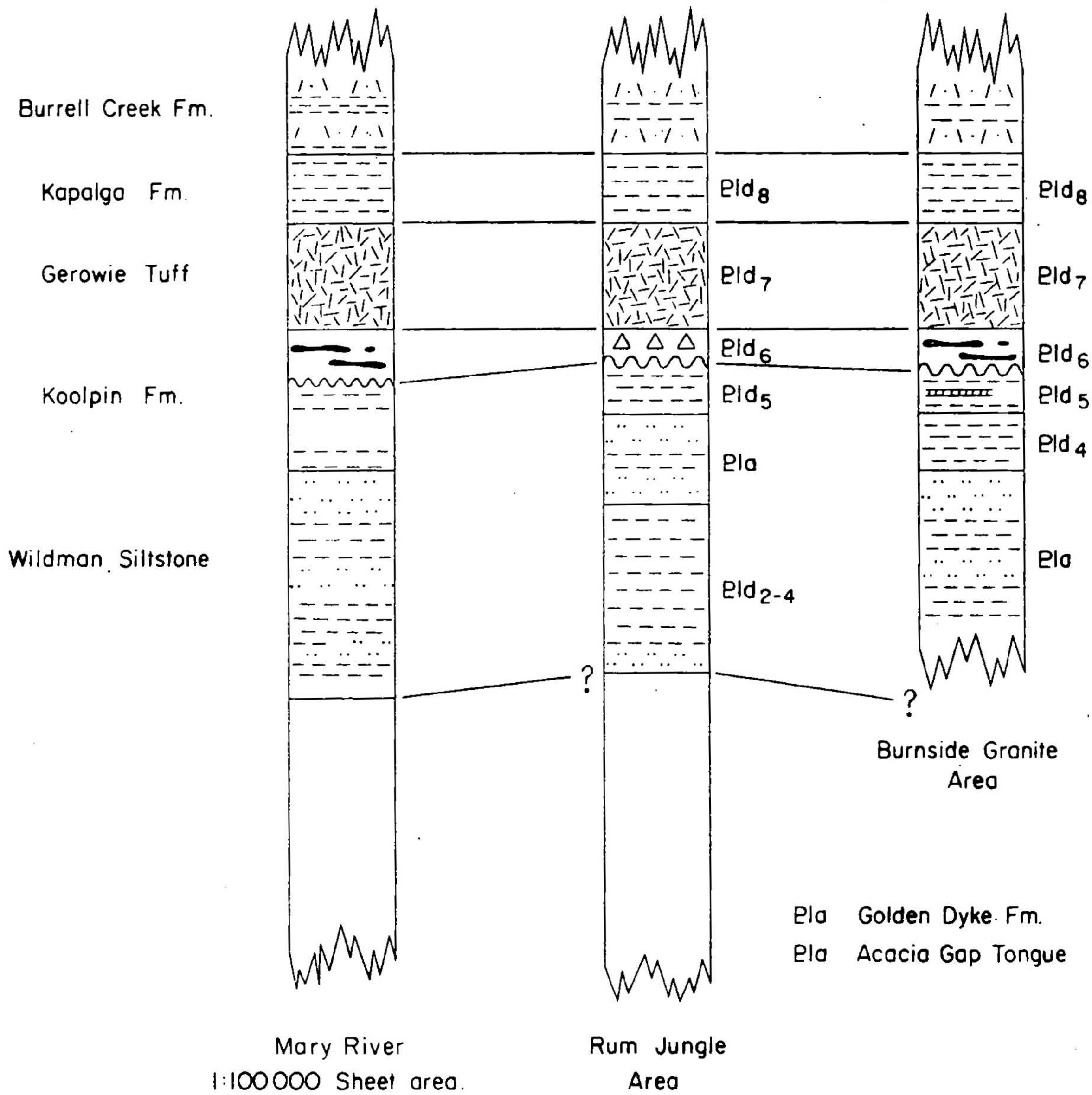

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Fig. M11 New stratigraphic nomenclature and revised correlations for Batchelor 1:100 000 Sheet area.

Underlying the Acacia Gap Tongue east of Batchelor are rocks previously described as units Ꝑld$_{1-5}$ of the Golden Dyke Formation; these are now thought to be Masson Formation or Wildman Siltstone. Ferruginous arkose and rare ferruginous siltstone have been variously assigned to units Ꝑld$_{3}$, $_{4}$, or $_{5}$. Unit Ꝑld$_{2}$ is generally a fine grey quartzite, commonly quartz-veined, but in an area 8 km east of Batchelor it consists of feldspathic arenite with small interbeds of laminated fine siliceous ignimbrite(?) adjacent to a large ridge of quartz-veined fine silicified tuff(?) containing minor disseminated pyrite and chalcopyrite, and minor malachite staining in joints and fractures. Unit Ꝑld$_{1}$ consists of carbonaceous shale and silicified calcareous siltstone; in places the siltstone directly overlies carbonate and silicified carbonate rocks of the Coomalie Formation.

Unit Ꝑlo$_{1}$ of the Coomalie Dolomite consists of brecciated saccharoidal quartzite (?silicified recrystallised carbonate) in a ferruginous fine silty matrix, and looks more like a 'laterite' formed during the Lower Proterozoic/Adelaidean hiatus. Unit Ꝑlo$_{2}$ is a quartz arenite which should not be included in the Coomalie Dolomite, but rather in the underlying Crater Formation which contains very similar arenite. The Coomalie Dolomite also contains coarse-grained carbonate rocks which appear to be pseudomorphous after gypsum in places. Silicified algal mats, circular structures, and Conophyton sp. are present also.

Beds of carbonate pseudomorphs after halite and gypsum are contained within the Celia Dolomite, which underlies the Crater Formation.

TIPPERARY SHEET AREA, by I.H. Crick, R.S. Needham, and G.C. Lau (NTGS)

Further traverses were made to positively identify the Koolpin Formation and Gerowie Tuff in parts of this area. The Gerowie Tuff crops out in the north-east of the Sheet area around a core of amphibolite, and has a distinctive white photo-pattern. Elsewhere - for example, along the Cosmopolitan Howley Anticline - the distinctive photo-pattern and the characteristic dark grey chert are absent. A report was prepared by G.C. Lau (NTGS) on the barite-fluorite-lead-zinc mineralisation discovered in 1977, 15 km south of the Tipperary homestead (NTGS Report 77/4). Lau also completed 9 days' fieldwork in the centre of the Sheet area where Oolloo Limestone is well exposed, logged samples collected in 1977, and finished photocompilation.

MUNMARLARY AREA DRILLING, by P.G. Stuart-Smith and R.S. Needham

An easterly traverse of eighteen scout drill holes to fresh bedrock was designed to test the sequence flanking the western margin of the Nanambu Complex, which could then be compared to results of similar traverses drilled off its eastern margin (Fig. M12). Owing to saturated clayey ground, the traverse could not be extended westwards to the South Alligator River as planned. The dominant rock types intersected were massive dolomite and micaceous dolomite: lesser mica-quartz and chlorite-mica schist are present at the eastern end of the traverse (holes East Alligator 14-18 and Field Island 2-4 and 11-14), and mica-quartz schist, feldspar-mica schist, dolomite, and clay at the western end (holes Field Island 5-10). The traverse appears to be within the Cahill Formation, most probably entirely within the 'lower member'. The result gives weight to the concept of a greater development of 'lower member' west of the complex, and possible facies change of the 'upper member' into Mount Hooper Sandstone which crops out on the western side of the South Alligator River about 10 km west of the western end of the traverse.

DIAMOND DRILL HOLE INTO CAHILL FORMATION, by M.J. Roarty

A 501.25 m continuously cored hole was drilled by N.T. Mines Branch at a depression of 60^{o} and an azimuth of 060^{o} in the Cahill 1:100 000 Sheet area (grid reference 395020) to obtain fresh samples of Cahill Formation about 11.6 km east of the South Alligator River bridge.

The hole intersected 77.05 m of siltstone, unconsolidated sand, claystone, and sandstone with a clay matrix of possible Cretaceous age, unconformably overlying the Cahill Formation. The Cahill Formation consists of micaceous schist, quartz-mica schist, silicified carbonate rock, massive carbonate rock with lenses of schist, and amphibolite.

Fine bands in carbonate rock near the bottom of the hole are quartz-sillimanite mica schist containing minor andalusite; they represent argillaceous sediment metamorphosed to the low-amphibolite facies. The fine banding appears to be primary, the mica- and sillimanite-rich bands representing clay-rich lamellae in a fine, quartz-rich sandstone.

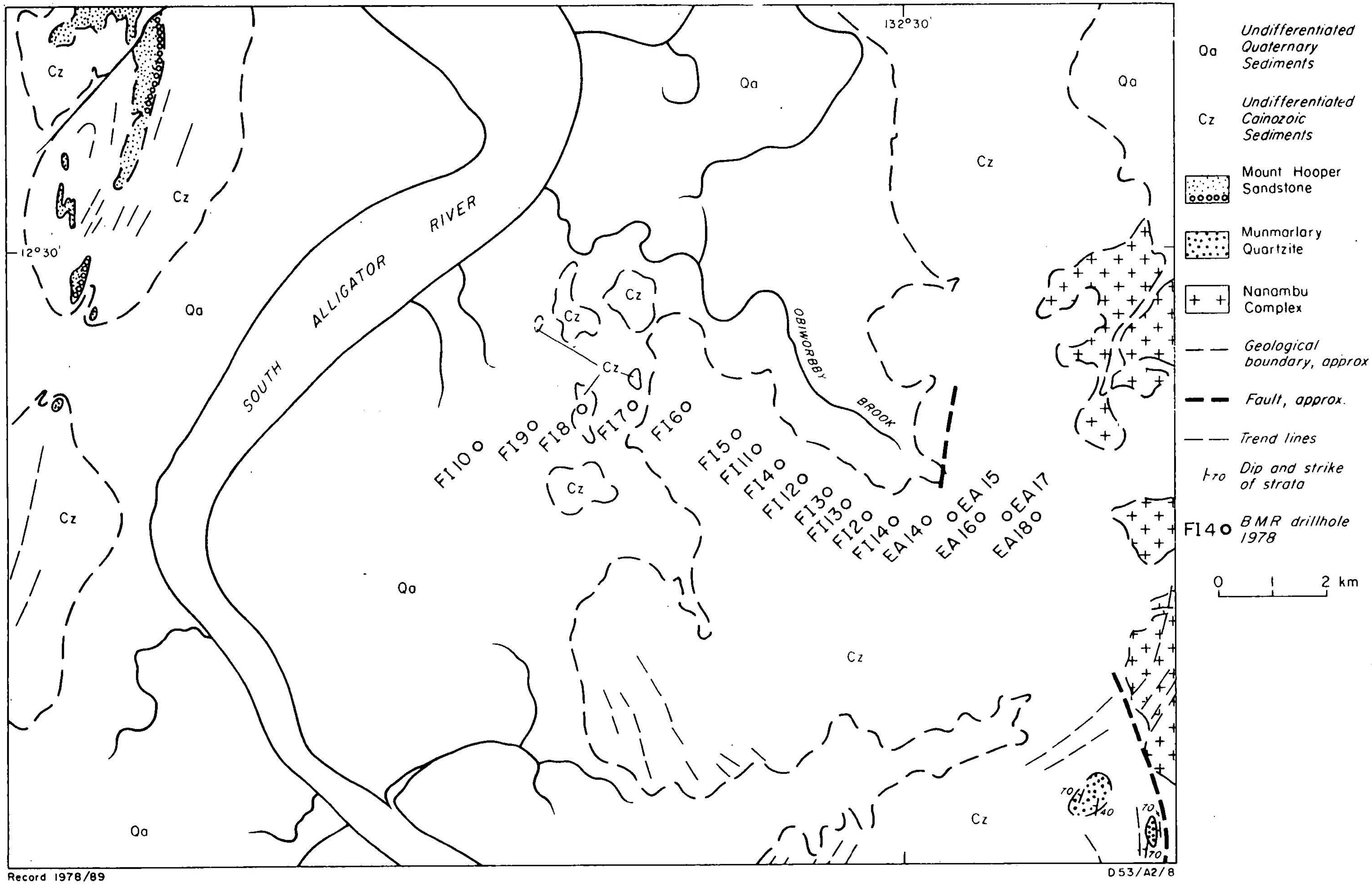

Fig. M12 Generalised geology and drillhole locations, Munmarlary area

The amphibolite could be either a metamorphosed basic igneous rock or a calcareous sediment.

A gamma log was run to 428 m, but no significant radioactivity was recorded. A hand-held scintillometer was run over the entire core, and again no significant radioactivity was noted.

Roarty prepared on report on the drill hole (NTGS Report 78/2) which includes lithological and gamma logs, and thin-section descriptions.

ANTARCTICA

by

R.J. Tingey

STAFF: R.J. Tingey (leave until 31 August), J.W. Sheraton, L.A. Offe, L.P. Black (part time); D.J. Ellis (now with University of Tasmania)

INTRODUCTION

BMR geological investigations in Antarctica form part of the multidisciplinary scientific research program of the Australian National Antarctic Research Expedition (ANARE), and are supported by the logistical resources of the Antarctic Division, Department of Science. Scientific research in Antarctica is specifically commended by the Antarctic Treaty to which Australia is signatory, and is construed to be consistent with, and evidence in support of, Australia's claim to sovereignty over the Australian Antarctic Territory - an area nearly as large as Australia and almost half of Antarctica.

FIELD ACTIVITIES

Field research associated with the systematic geological investigation of Enderby Land (52°E, 65°S), in the western part of Australian Antarctic Territory, continued in the 1977-78 summer field season, having started in the 1974-75 season. Following the major geological mapping effort in the 1976-77 season, the main emphasis in 1977-78 was on sample collection for geochronology. This is of key importance in mapping areas with scattered and discontinuous outcrops of basement metamorphic and igneous rocks, and is intrinscally interesting so far as Enderby Land is concerned because of results reported by Soviet geologists (see below and *Sobotovich & others, 1976). Black travelled to Enderby Land for this work (see report under Metalliferous Laboratories), and was accompanied by Offe who co-ordinated activities, and continued structural observations. The BMR geologists were accompanied in the field by several University geologists. Dr P.R. James, of the University of Adelaide, worked especially closely with Black in making a regional appraisal of Enderby Land's structural geology. Mr A. Griffin, of the University of Melbourne, mapped structural detail in the relatively well exposed areas around Amundsen Bay, and Dr E.S. Grew, a United States geologist working as a Fulbright Scholar at the University of Melbourne, collected specimens of high-grade metamorphic rocks with special regard to the assemblage sapphirine-quartz and osumilite-bearing rocks. Such University research is complementary to BMR investigations, and has been encouraged by BMR.

Other ANARE groupd continued field programs of significance to the Enderby Land geological investigations. These included the Division of National Mapping's completion of high-level (6100 m) colour vertical aerial photography of Enderby Land and nearby Kemp Land, and flying of low-level (3500 ft to 5000 ft a.s.l.) photographic sorties over selected outcrop areas. However, poor weather and other factors restricted opportunities for airborne radar ice-thickness profiling and the associated BMR program (see Geophysical Branch Summary of Activities) of aeromagnetic profiling. Aeromagnetic surveys are important for gaining some appreciation of the nature of the sub-glacial bedrock, and remain a major objective for future fieldwork.

The final phase of ANARE summer operations in Enderby Land was scheduled for the coming 1978-79 summer season, but has had to be postponed for one year because of logistics problems encountered by the Antarctic Division, Department of Science. The 1977-78 season saw the first full participation of University geologists in ANARE summer field operations, and the postponement of the final phase of Enderby Land operations, planned for 1978-79, is particularly unfortunate for them as well as for BMR geoscientists.

*Sobotovich, E.V., Kamenev, E.N., Komatistyy, A.A., & Rudnik, V.A., 1976. The oldest rocks of Antarctica (Enderby Land). International Geology Review, 18, 4, 371-387.

OFFICE AND LABORATORY STUDIES

Sheraton continued geochemical studies of metamorphic rocks from Enderby Land (see under Metalliferous Laboratories) as a sequel to his paper on the origin of charnockitic rocks in MacRobertson Land, Antarctica (Sheraton - in press). He also described thin sections of specimens collected in the 1976-77 field season, and collaborated with D.J. Ellis and W.B. Dallwitz in a study of petrogenetically significant sapphirine-quartz and osumilite-bearing rocks that are so widespread in Enderby Land (see under Metalliferous Laboratories).

Offe also described thin sections of rocks from Enderby Land, and assembled structural data from all parts of Enderby Land and Kemp Land. His joint (with Sheraton) synthesis of these data is described below.

Tingey was unable to describe the thin sections of the rocks he collected in Enderby Land in 1976-77 because of his absence overseas on leave. Writing up of work for that season is consequently delayed. However, Tingey undertook, as part of his Diploma in Polar Studies course at the Scott Polar Research Institute, Cambridge, U.K., an extensive study of the geology of the metamorphic basement shield of East Antarctica. The resultant thesis is being prepared for issue as a BMR Record.

While overseas Tingey also represented Australia/Oceania at meetings of the I.U.G.S. Commission for the Geological Map of the World at UNESCO Headquarters in Paris in March, 1978. He also visited Hannover, West Germany, to describe Australian experience and results in Antarctic geology to the Bundesanstalt für Geowissenschaften und Rohstoffe, the Federal German Government's national geological agency; this visit was made under the aegis of the Australia - Federal Republic of Germany Science Agreement. In Britain Tingey was invited to lecture on Antarctic geology at the Universities of Durham, Keele, Newcastle-upon-Tyne, and Birmingham, and gave a seminar on the same topic at the Scott Polar Research Institute.

STRUCTURAL GEOLOGY OF ENDERBY LAND

Offe and Sheraton have made a tentative synthesis of the structural geology of Enderby Land, and Griffin has reported results of more detailed studies in the Amundsen Bay area. There is a large measure of agreement between these appraisals.

Offe and Sheraton conclude, in a draft manuscript, that two or three distinct folding events are recorded in the granulite-facies metamorphic rocks of Enderby Land. The oldest structures are small-scale intrafolial folds which are apparently of similar age to major tight to isoclinal folds, and were formed during the deformation which accompanied the granulite-facies metamorphism. This deformation is post-dated by structures whose axial planes dip at moderate to steep angles, and are inclined at a large angle to earlier foliations.

A suite of essentially unaltered and undeformed dolerite dykes intersects these last structures, and some similar little deformed, but metamorphosed, dykes appear to have been emplaced during the waning phases of the granulite-facies metamorphism. The unaltered dykes are post-dated by local shearing that may be associated with the formation - probably about 1000 m.y. ago - of the 'Rayner Complex', in which no unmetamorphosed basic dykes have been noted. In Kemp Land locally discordant basic dykes now have granulite-facies mineral assemblages.

Structural studies thus document the complexities of the basement geology of Enderby Land that were described in the 1977 Annual Summary. Black hopes that the structural observations of Dr James will enable him to correlate his geochronological results with particular deformation and/or folding episodes in the manner that he has recently described from the Georgetown area of North Queensland (Black & others, in press).

ENDERBY LAND GEOCHRONOLOGY

Enderby Land has held some interest for geochronologists and Antarctic geologists since the Soviet geologists, the late Dr Ravich and Grikurov reported, to the 1973 Gondwana Symposium, that rocks from there had yielded isotopic ages of about 3800 m.y. Details were not published, but in

1976 an English translation of a 1974 paper by Sobotovich & others described whole-rock lead and thorium-lead isochron age determinations of 4000 ± 200 m.y. on rocks from the Fyfe Hills, Enderby Land. More information, including a map that has enabled the sample locality to be identified precisely, was given at the third International Symposium on Antarctic Geology and Geophysics at Madison, Wisconsin, U.S.A., in 1977.

The 4000 ± m.y. age determinations make these Enderby Land rocks the oldest known on Earth, although there must be doubts as to the validity and interpretation of these ages in the absence of corroborative dating on either a local or a regional scale. Such determinations are a high priority for Black's geochronological studies.

There appears to be some prospect, from regional considerations, that very old metamorphic rocks occur in Enderby Land. These considerations (which were outlined in the 1977 Annual Summary) are based upon the presence of cross-cutting basic intrusives in areas of older metamorphic rocks, and their absence, except as deformed and metamorphosed relics, from areas where similar grade but considerably younger metamorphic rocks occur. In western Enderby Land, where basic dykes are not seen, a Rb-Sr whole-rock isochron age of 987 ± 60 m.y. has been reported from the Rayner Complex. Cross-cutting basic dykes are abundant in central and eastern Enderby Land where the Soviet geologists report the very old ages, and comparison with geochronological results from MacRobertson and Princess Elizabeth Lands farther east suggests that the high-grade metamorphic rocks of this part of Enderby Land may well be of Archaean age. The distinction between groups of broadly similar metamorphic rocks on the basis of the presence or absence of cross-cutting basic dykes must be made cautiously, but has been successfully employed in 'classic' Precambrian terrains such as northwest Scotland and Greenland.

GEOLOGICAL INVESTIGATIONS IN QUEENSLAND AND PAPUA NEW GUINEA

Supervising Geologist: K.R. Walker

MOUNT ISA - LAWN HILL PROJECT

by

G.M. Derrick and I.P. Sweet

STAFF: BMR: G.M. Derrick (Project Leader), I.P. Sweet, R.M. Hill (resigned 20.9.78), R.W. Page (Geochronology, part time), A.G. Rossiter and P.A. Scott (Geochemistry), J. Stirzaker (Draftsman)

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

W. Perkins, of Mount Isa Mines Ltd, worked with the party from 14 August to 15 September.

AIMS: To research the Precambrian rocks of the Cloncurry Complex 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.
RELATED INVESTIGATIONS: Geochronology and geochemistry (see Metalliferous Laboratories report), Duchess geology, and Lawn Hill-Westmoreland geology.

FIELD ACTIVITIES

MAMMOTH MINES, MOUNT OXIDE, GREGORY DOWNS, MYALLY AND UNDILLA 1:100 000 SHEET AREAS

Introduction

Field research in 1978 saw the linking of the Mount Isa and Lawn Hill projects. The Mammoth Mines, Mount Oxide, Gregory Downs, Myally, Coolullah, and parts of Undilla 1:100 000 Sheet areas were investigated using 60 hours of helicopter traverses combined with numerous vehicle and foot traverses during July, August, and September from a base camp near Gunpowder township. Together with the work of the Duchess project, field investigations of the Cloncurry Complex have now been completed. The geology and stratigraphy of the areas investigated are shown in Figures M13 and M14. The geology of the Coolullah Sheet area is described below.

Field research this year has resulted in:

(1) rationalisation of stratigraphy from Mount Isa to Lawn Hill, and elimination of the term 'Ploughed Mountain Beds',

(2) greater understanding of the Mount Gordon Arch, a major long-acting palaeogeographic feature grossly coincident with the Mount Gordon Fault Zone,

(3) the discovery of Eastern Creek Volcanics in the cores of domes well to the west of the Mount Gordon Fault Zone,

(4) delineation of the Fiery Creek Volcanics, a rhyolite-trachyte-basalt suite with a thick basal sandstone-conglomerate member, bounded top and bottom by regional unconformities,

(5) recognition of a westwards increase in the proportion of stromatolitic dolomite, purple shale, and siltstone in sandstone of the Myally Subgroup, and recognition of halite casts, stromatolites, and trachybasalt flows in the Quilalar Formation near Alhambra,

(6) recognition of widespread, mainly intertidal to supratidal carbonate environments in the McNamara Group (Mount Isa Group equivalents) west of the Mount Gordon Arch, characterised by basin-wide chert (stromatolitic and non-stromatolitic) and tuff marker beds,

and (7) the observation that most copper mineralisation, mainly of the diagenetic-epigenetic breccia type, is related to the Mount Gordon Arch and Fault Zone, and to other faults; some is related to trachytic dykes and volcanic breccia similar to those at Redbank. Lead-zinc mineralisation occurs in the Lady Loretta Formation, which appears to be regionally prospective for lead and zinc.

More detailed comments follow.

Stratigraphy, lithology

The oldest rocks are acid volcanics of the Leichhardt Metamorphics and Argylla Formation, which occur in the Myally Sheet area as a northerly extension of the Ewen block in the Alsace Sheet area to the south. They are intruded by the Ewen Granite; both volcanics and granite are overlain unconformably by the Eastern Creek Volcanics. The Leander Quartzite is not preserved along the western edge of the Ewen block, but underlies the Eastern Creek Volcanics in a fault wedge in the southeast of Mammoth Mines Sheet area.

The Eastern Creek Volcanics have been deposited in a rapidly subsiding graben or half-graben. The eastern edge is marked by abundant conglomerate wedges overlying basement, and by thinning of basalt. A 6000 m-thick sequence of apparently very fresh basalt and minor sandstone and tuff near Gunpowder marks the zone of maximum downwarp in the rift. This zone was extensively sampled for geochemical studies. The western boundary of the rift is not exposed; only the upper unit (Pickwick Metabasalt Member), is present, and basalt within it appears to thin from 1000 m near Gunpowder to 300 m in the central part of the Mount Oxide Sheet area. Magnetic and gravity studies suggest that Eastern Creek Volcanics underlie much of the area west of the Mount Gordon Fault Zone at relatively shallow depth.

Shallow-shelf feldspathic sandstone of the Myally Subgroup overlies the Eastern Creek Volcanics conformably. The four-fold division of other areas is recognizable; the topmost unit (Lochness Formation) becomes increasingly dolomitic, and massive feldspathic sandstone (Whitworth Quartzite) becomes more ferruginous and more silty westwards. The subgroup thins eastwards across the Ewen block, southwest across the Mount Gordon Arch, and northwest across the Mount Oxide Sheet area.

The Quilalar Formation contains a lower unit W and an upper unit X; units Y and Z, formerly a part of the formation in the Alsace Sheet area, overlie unit X unconformably, and are now considered to be a basal sedimentary facies of the Fiery Creek Volcanics. Units W and X, mainly quartzite and dolomite, respectively, are exposed in a northwesterly arc across the Myally and Mount Oxide Sheet areas, but are absent from the Mammoth Mines Sheet area.

Stromatolites occur in both units, but they are more common and diverse west of the Mount Gordon Fault Zone. Near Alhambra, unit W contains the 30 m-thick trachybasaltic Alhambra Volcanic Member; unit X contains thin green tuff bands, halite casts, orthoquartzite and purple dolomitic sandstone lenses, and calc-silicate rocks within 1 km of the Weberra Granite. These units are correlated ultimately with the Ballara Quartzite and Corella Formation far to the southeast, and were possibly continuous across Ewen and Kalkadoon basement blocks.

The Weberra Granite is a weakly zoned, medium-grained, felsic pluton, which intrudes the Quilalar Formation. Its relationship with the Fiery Creek Volcanics is not known. Acid dykes and breccia pipes which intrude the Myally Subgroup and the Quilalar Formation west and south of Alhambra are probably related to the granite, and contain some copper mineralisation.

A major regional unconformity separates the Fiery Creek Volcanics from older rocks. Thick sequences of basal conglomerate and purple sandstone and siltstone are found east and northeast of Mount Gordon, but are less well developed to the west and northwest. The basal unconformity becomes increasingly angular towards the west of the Mount Oxide Sheet area, and significant folding and erosion of older rocks before Fiery Creek deposition is indicated. The stratigraphy of the volcanic members of the Fiery Creek Volcanics is complex, but a generalised sequence is, from the top,

amygdaloidal basalt
rhyolitic agglomerate
fluidal rhyolite, quartz-feldspar porphyry
amygdaloidal basalt, trachybasalt

The agglomerate consists largely of rhyolite fragments, and occurs in the east of the Mount Oxide Sheet area; rhyolite is confined to the central and western areas of Mount Oxide, and basalt is widespread. Both volcanic and sedimentary members thin southwards along the Mount Gordon Fault Zone, and no volcanics are as yet recorded from the Mammoth Mines Sheet area.

A generally low-angle but regional unconformity separates the Fiery Creek Volcanics from the overlying Surprise Creek Formation, a mainly conglomerate-sandstone (unit A) and sandstone-siltstone (units B, C, D) sequence. The formation thins southwestwards - e.g., from over 1000 m in the east of the Gregory Downs Sheet area to 200 m in the west of the Mount Oxide Sheet area, and from over 1500 m in the Myally Sheet area to an 80 m-thick veneer of siltstone, conglomerate, and ferruginous regolithic breccia along the Mount Gordon Arch and Fault Zone south of Gunpowder. Virtually all rocks previously mapped as Ploughed Mountain Beds in the east of the Gregory Downs Sheet area are Surprise Creek Formation.

McNamara Group

As originally defined by Cavaney (1975), the basal formation of the McNamara Group, the Mammoth Formation, includes what we have mapped separately as Surprise Creek Formation. The Torpedo Creek Quartzite Member of the Mammoth Formation now becomes the basal unit of the McNamara Group, overlain by Gunpowder Creek Formation. Cavaney subdivided the 'old' Paradise Creek Formation into the Paradise Creek Formation, Esperanza Formation and Lady Loretta Formation. Rocks previously called Ploughed Mountain Beds can be subdivided into Fiery Creek Volcanics, Surprise Creek Formation, and McNamara Group.

The McNamara Group is equivalent to the Mount Isa Group; the dual nomenclature nominally describes shelf and basinal facies, respectively, and may also coincide with deposition west and east of the Mount Gordon Arch.

The Torpedo Creek Quartzite is a thin but widespread quartz sandstone blanket, generally concordant with underlying siltstone of the Surprise Creek Formation. Gypsum casts are present in the Qqurtzite 1 to 5 km west of Mount Gordon and Mount Oxide.

The Gunpowder Creek Formation is mainly grey-green and purple laminated siltstone, and has fewer load castings than the Surprise Creek siltstone, which it resembles. It also includes fine sandstone, dolomite, and carbonaceous shale, and thins northwards and onto the Mount Gordon Arch, where only 10 m is preserved.

A grey, 2 to 5 m-thick laminated chert - the Oxide Chert Member - marks the base of the overlying Paradise Creek Formation, a sequence of laminated dolomite, limestone, dolomitic siltstone, and tuff marker beds in the lower part, and stromatolitic and intraclastic dolomite in the upper part; cauliflower structures (pseudomorphous after anhydrite) occur in some beds.

A prominent siltstone/chert marker unit, the Esperanza Formation, contains spectacular Conophyton. It is overlain by the Lady Loretta Formation, a dolomitic siltstone in the south, which becomes more dolomitic northwards. A zone of carbonaceous and pyritic siltstone and shale contains the Lady Loretta Pb-Zn deposit, and can be traced in the middle of the formation in the west of the Mount Oxide Sheet area. Farther north, near Lawn Hill, siltstone and shale are rare, and intraclast dolomite containing stromatolites and anhydrite pseudomorphs is dominant. The topmost units in the McNamara Group - the Shady Bore Quartzite and the Riversleigh Siltstone - crop out in the west of the Mammoth Mines and in the east of the Undilla Sheet areas.

Depositional environments, palaeogeography

The palaeogeographic development of the Mount Oxide region (Fig. M13) is intricately linked to evolution of a major Proterozoic rift structure, the Leichhardt River Fault Trough (Glikson & others, 1976; Plumb, Derrick, & Wilson, in prep.), which is 300 km long and 50 km wide. A 200 million-year history of fault movements within and at the margins of the rift, variable subsidence rates, and preservation of shallow-water platform environments marginal to the rift provide a framework within which local environments can be better understood.

Three hinge zones or arches have greatly influenced sedimentation in the Mount Oxide region - the Quilalar Arch marks the unstable, elevated eastern edge of the basin active in Haslingden Group time; the Mount Gordon Arch modified sedimentation and volcanism possibly as early as Eastern Creek Volcanics time, and through to McNamara Group time; and the Lawn Hill palaeo-high in the far northwest of the area, towards which the lower McNamara Group thins and becomes more dolomitic.

The Mount Gordon Arch divides the region into two broad sub-basins: the eastern sub-basin is characterised by thick but mainly shallow-water volcanic, sandstone, and siltstone sequences, deposited in a steadily sub-

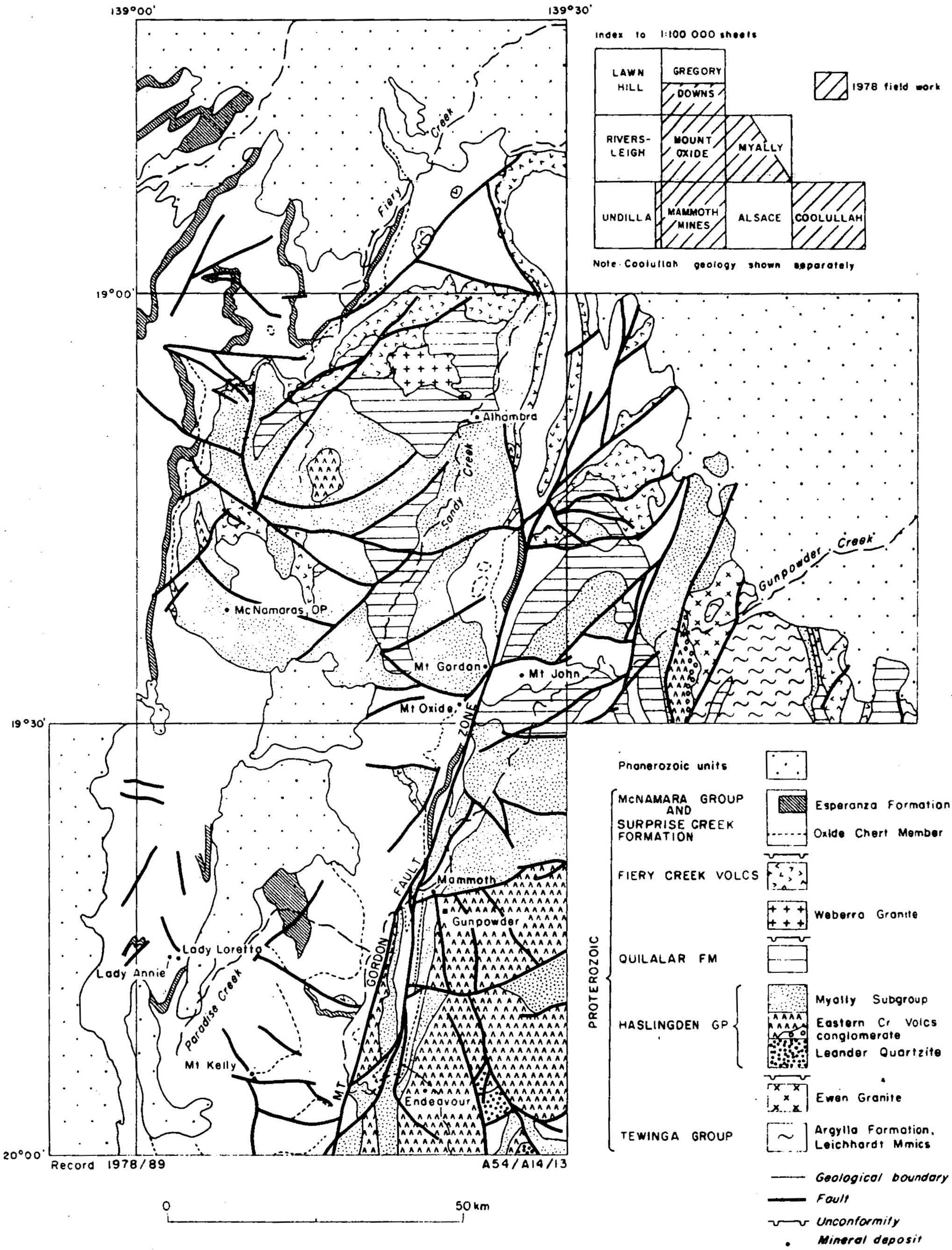

Fig.M13 Geological sketch map, Mount Oxide region, northwest Queensland siding basin; and the western sub-basin, characterised by generally thinner and more condensed sequences deposited in very shallow subtidal to supratidal, commonly evaporative environments, in which stromatolites thrived. Channels between stromatolites filled with intraclast grainstone indicate high-energy conditions, and laminated and thin-bedded dolomite in the Gunpowder Creek and lower Paradise Creek Formations suggests low-energy lagoonal and marine peritidal environments.

Economic geology

Copper mineralisation is present in at least four different settings throughout the region.

1. In amygdaloidal flow tops of the Eastern Creek Volcanics, as chalcopyrite.

2. In trachybasalt dykes 3 km southeast of Alhambra, as secondary copper minerals; the dyke rock appears to be the primary source of copper, and minor mineralisation occurs in fractures and along bedding planes of the nearly flat-lying dolomitic sandstone and siltstone country rock of the Lochness Formation. Trachytic fissure breccias and possible breccia pipes 5 to 10 km west-southwest of Alhambra intrude Quilalar Formation dolomitic sandstone, siltstone, and dolomite, and contain copper traces in the breccia matrix. This setting appears similar to Redbank-type mineralisation.

3. In possible stratiform and stratabound settings, as chalcopyrite in dolomite and dolomitic and carbonaceous siltstone of the upper Gunpowder Creek Formation. Mount Kelly is a possible example. Possible stratabound mineralisation also occurs in unit D siltstone of the Surprise Creek Formation at Mount John.

4. In matrix infilling of tectonic and possible sedimentary breccias, as chalcocite, chalcopyrite, and secondary copper minerals. Many such deposits are located along the Mount Gordon Fault Zone, a major zone of brittle failure, where copper has migrated from enriched sedimentary or volcanic source rocks into breccia zones.

The Endeavour mine workings followed a quartz vein near sheared dolerite cutting cleaved Eastern Creek Volcanics; the Bluff and Mount Gordon lodes occur in brecciated sandstone of Myally Subgroup juxtaposed against

Gunpowder Creek Formation. The Mount Oxide lode is a mineralised breccia in which highly carbonaceous shale of the Gunpowder Creek Formation, Oxide Chert Member, and Paradise Creek Formation dolomites are faulted together. Lady Annie may be a similar type of deposit enriched by supergene processes. In the southwest of the Mount Oxide Sheet area, shallowly dipping, reddish, feldspathic sandstone of the Myally Subgroup is brecciated locally along thin shears; copper is present in the breccia matrix, and it has probably originated from the sandstone country rock.

Mammoth, the largest deposit in the area, is located in reddish feldspathic sandstone breccia in topmost Myally Subgroup; the latter is unconformably overlain by a sedimentary breccia (?talus deposit) of the Surprise Creek Formation, which is overlain by siltstone, dolomite, and carbonaceous shale of the Surprise Creek and Gunpowder Creek Formations. The unconformity is displaced by faulting. Mineralisation appears to be secondary, and controlled by abundant breccia pore space (both tectonic and sedimentary), unconformable overlap of units, and capping of the breccia zone by carbonaceous and dolomitic rocks. The source of the copper was probably the associated red-bed sediments and possibly Eastern Creek Volcanics at depth, from which copper has been leached and transported into favourable structural settings.

Lead-zinc mineralisation occurs in the Lady Loretta Formation, at Lady Loretta. Company activity in the region has focused on this unit, using the underlying Esperanza chert marker for stratigraphic control. Small galena-baryte showings occur in pseudomorphs after anhydrite in the Paradise Creek Formation.

Geochemistry

Systematic geochemical stream-sediment sampling of the Mammoth Mines Sheet area was completed, and progress on this work is recorded in the Metalliferous Laboratory report. Numerous gossanous zones were sampled throughout the area mapped in 1978, but results are not yet available. Sampling of granite throughout the Mount Isa-Cloncurry region was undertaken by L.A.I. Wyborn, as part of a research project on their geochemistry. Details are also presented in the Metalliferous Laboratory report.

COOLULLAH 1:100 000 SHEET AREA, by I.H. Wilson, G.S.Q.

The geology of the Coolullah 1:100 000 Sheet area is shown in Figure M14. Mapping was done by I.H. Wilson (GSQ), traversing by vehicle from the Gunpowder base camp.

In the west and southwest of the Sheet area the sequence from youngest to oldest is as follows:

brown labile sandstone	(Surprise Creek Formation?)
black-weathered and laminated calc-silicate rocks with intercalations of garnetite and para-amphibolite	(Corella Formation)
grey quartzite with basal conglomerate and arkose	(Ballara Quartzite)
pink porphyritic acid volcanics, intrusive porphyry and minor sediments	(Argylla Formation)
metabasalt	(Magna Lynn Metabasalt)
grey porphyritic acid volcanics	(Leichhardt Metamorphics)

Near the eastern limit of outcrop, the pink acid volcanics are highly sheared, and aplite veins are common in this unit and the overlying Ballara Quartzite and Corella Formation. Dolerite dykes are also common. The structure is much more complex than that indicated on the 1:250 000 Dobbyn Sheet, and is dominated by tight (to isoclinal in the east) north-trending folds and oblique faults.

In the Boomarra Horst, the sequence consists of black slate (with minor copper), black laminated calc-silicate rocks with abundant aplite veins, and grey quartzite with conformable amphibolite bands and aplite veins. The quartzite is the most extensive and probably the oldest of these units, and is assigned to the Soldiers Cap Group. The calc-silicate rocks are intruded by dolerite, and closely resemble rocks of the Corella Formation. No large granite bodies were located (cf. Dobbyn 1:250 000 map), but aplite dykes are abundant.

Calc-silicate rocks, aplite veins, and sheared grey quartzite extend from the Boomarra Horst into the Kamileroi 1:100 000 Sheet area.

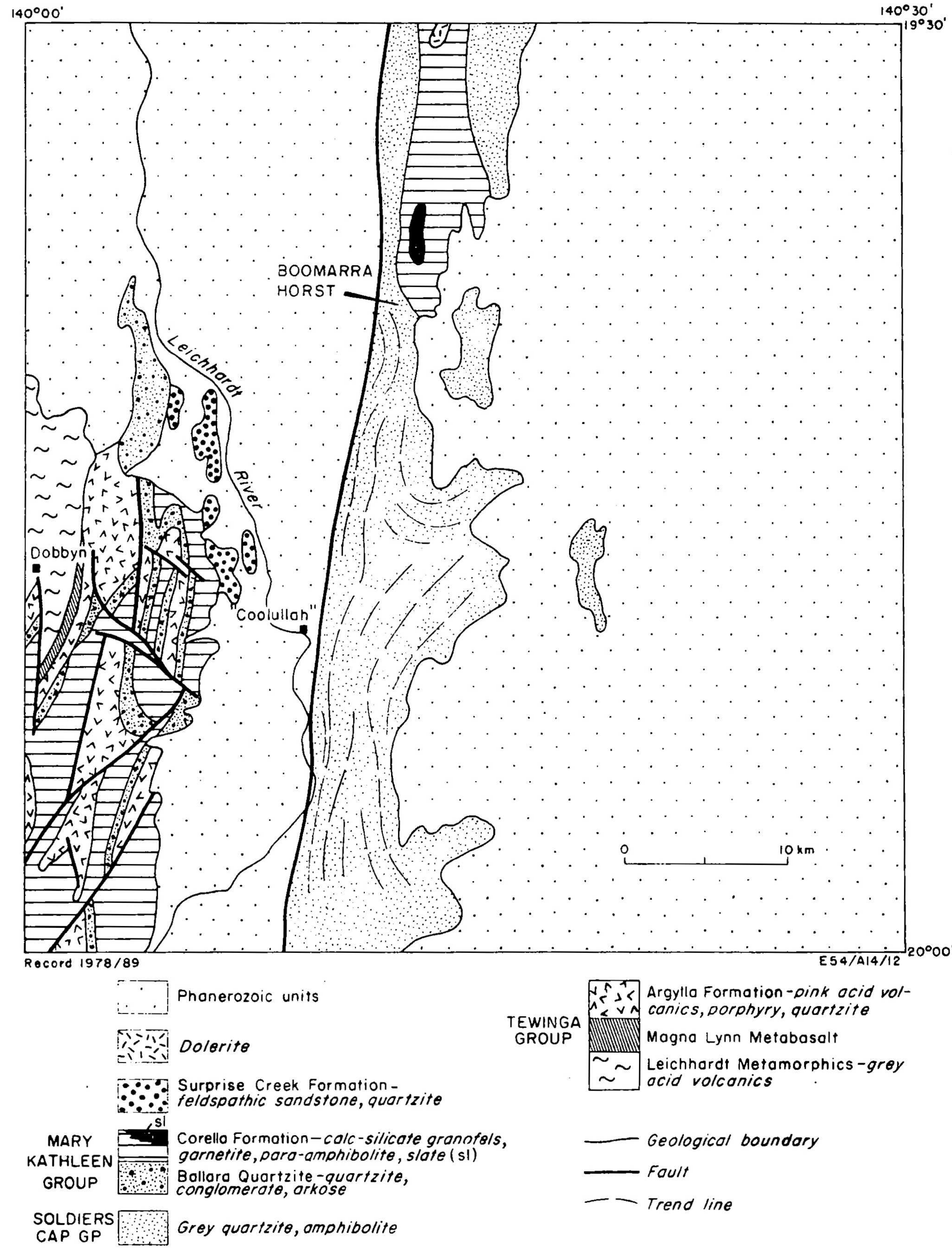

Fig. M 14 Geology, Coolullah 1:100 000 Sheet area

OFFICE ACTIVITIES

Maps

The Kennedy Gap, Quamby, and Prospector 1:100 000 maps were prepared for colour edition publication. The Mount Oscar and Alsace preliminary-edition maps are in preparation, and preparation of 1978 field-compilation sheets has commenced.

Reports, Publications

A Record was issued of Lawn Hill 1:100 000 field compilation sheets at 1:100 000 scale (BMR Record 1978/63), and a Record on the Kennedy Gap 1:100 000 Sheet area is being processed. A paper on the stratigraphic nomenclature of the igneous rocks was published in the Queensland Government Mining Journal, and a Report to accompany the Marraba 1:100 000 colour edition map was written. A paper was prepared by K.A. Plumb, G.M. Derrick, and I.H. Wilson on the geology of the McArthur-Mount Isa region, and was presented to the Third Australian Geological Convention of the Geological Society of Australia, at Townsville.

Miscellaneous

Throughout the year project staff prepared talks for a Precambrian discussion group and the BMR lecture series on Lawn Hill geology, Lunch Creek Gabbro, and the Burstall Granite. Derrick attended meetings of the IGCP project on Metallogeny of the Precambrian.

Petrographic studies of Cloncurry and Alsace sampdes continued, and further geochemical work on the Overhang Jaspilite was carried out in conjunction with the BMR Laboratory.

WESTMORELAND PROJECT

by

I.P. Sweet

STAFF: I.P. Sweet

The project is part of the overall program to investigate the geology of the Precambrian rocks of northwestern Queensland; fieldwork was completed in 1974.

Since 1974 preliminary editions of the Hedleys Creek and Seigal 1:100 000 Sheets have been issued, the Westmoreland 1:250 000 Sheet has been revised, and explanatory notes for the Second (colour) Edition prepared, and three Records have been written.

During 1978 the preliminary 1:100 000 sheets were revised in preparation for publication as coloured maps. A Bulletin, combining the information contained in the three Records, is also in preparation.

The results of a geochemical survey of the Westmoreland region are discussed in the 'Geochemical Laboratories' section of this Summary of Activities.

DUCHESS PROJECT

by

D.H. Blake

STAFF: D.H. Blake (Project Leader), R.J. Bultitude, A.L. Jaques (from June), W.J. Perry (part time) C.M. Mock (part time), P.J.T. Donchak (GSQ), G.A. Young (draftswoman).

AIMS: The aims of the Duchess Project are to produce geological maps, at 1:100 000 scale, of the Precambrian parts of the Duchess and Urandangi 1:250 000 Sheet areas, and to review the stratigraphy, structure, geological history, and mineral potential of the area. The Precambrian rocks exposed belong to the Cloncurry Complex, as defined by Carter, Brooks & Walker (1961, BMR Bulletin 51), and are hosts to economic copper, silver, and cobalt mineralisation.

INTRODUCTION

Office work during the year consisted of map compilation, airphoto interpretation, petrographic studies, and report writing for the Duchess and Dajarra 1:100 000 Sheet areas by Blake, Bultitude, and Donchak. In addition W.J. Perry photointerpreted the Ardmore 1:100 000 Sheet area. The data Record for the Dajarra Sheet area, accompanied by the preliminary-edition map, was completed and issued as BMR Record 1978/46. The data Record and preliminary-edition map for the Duchess 1:100 000 Sheet area are awaiting final checking, and are expected to be completed by the authors by December 1978. The preliminary edition map of the Oban 1:100 000 Sheet area, compiled by C.M. Mock, is available, as also is a report on the geology of the Malbon 1:100 000 Sheet area by T.A. Noon (GSQ Record 1978/7).

Fieldwork was carried out from early June to mid-October. During this period Blake, Jaques, and Donchak mapped the Mount Merlin, Selwyn, and Mount Angelay 1:100 000 Sheet areas, and Bultitude mapped the Ardmore

1:100 000 Sheet area. This completes the planned systematic field research, as the other 1:100 000 Sheet areas involved (Oban, Duchess, Malbon, and Dajarra) were mapped during previous field seasons. However, some checking of critical field relationships in the project area will be necessary in 1979.

MOUNT MERLIN 1:100 000 SHEET AREA (Fig. M 15)

by A.L. Jaques

Precambrian rocks are exposed in the eastern part of the Mount Merlin Sheet area, where they form an apparently conformable succession which has been tightly to isoclinally folded about north-trending fold axes, and regionally metamorphosed to at least greenschist facies.

The oldest unit, the westernmost of the succession, is the Argylla Formation, which consists of metamorphosed acid volcanics, mainly rhyodacite lava, tuff (including some possible ignimbrite), and agglomerate, interbedded with metasediments-predominantly feldspathic arenite-and some schistose amphibolite. The Argylla Formation is overlain by a unit, mapped as Marraba Volcanics, of feldspathic arenite, phyllite, biotite schist, and subordinate metabasalt which is commonly amygdaloidal. An overlying unit of predominantly quartzose and feldspathic arenite with some metasiltstone and biotite schist and minor metabasite is mapped as Mitakoodi Quartzite. The Mitakoodi Quartzite is overlain by the Answer Slate, which consists of thinly bedded black slate, phyllite, micaceous siltstone, sericite and biotite schist, pyritic chert, and fine-grained meta-arenite. Slate and chert are most abundant near the base of the unit. The Answer Slate is intruded by numerous metadolerite bodies, predominantly sills. Some of these bodies are differentiated to granophyric dolerite.

A thick sequence of quartz-muscovite-biotite schist (with or without staurolite garnet and andalusite), slate, metasiltstone, phyllite, and calc-silicate rocks, mapped as Kuridala Formation, crops out along the eastern margin of the Sheet area. Lithologic similarities and stratigraphic relations suggest that this unit may be a facies equivalent of the Answer Slate. Both formations are overlain by the Staveley Formation, a sequence of calcarenite, calcilutite, calcareous shale, subordinate ferruginous and micaceous sandstone, siltstone, and shale, and minor slate near the base.

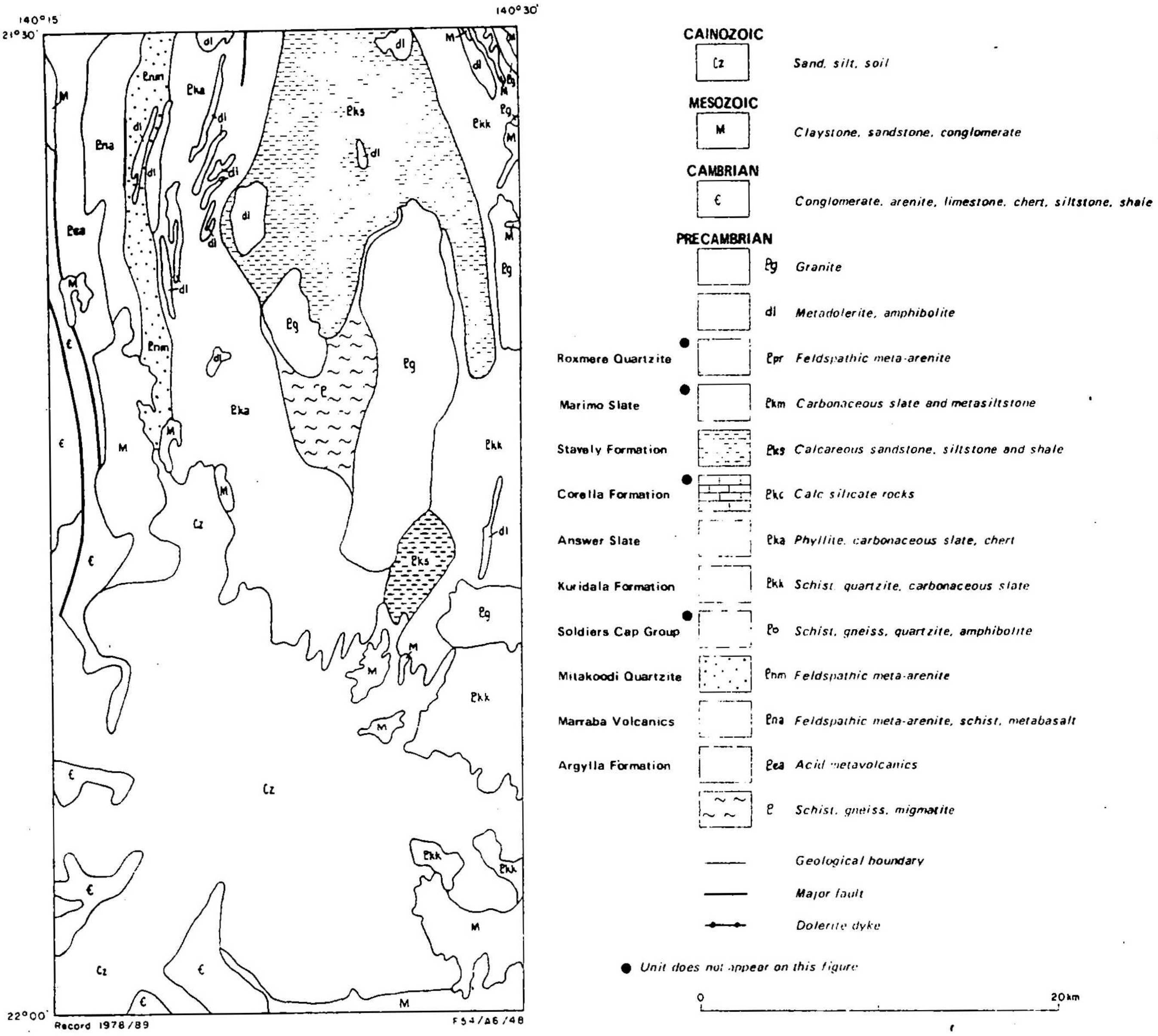

Fig M 15 General geology, Mount Merlin 1:100 000 Sheet area

The Staveley and Kuridala Formations and the Answer Slate are intruded by a large complex granite pluton, the Gin Creek Granite, which ranges from porphyritic biotite granite to muscovite-tourmaline granite, and is commonly foliated. The granite also intrudes stratigraphically enigmatic highly foliated quartz-feldspar-biotite schist, granitic and augen gneiss, and migmatite.

Quartz-hematite rocks, some banded, occur largely as stratabound bodies mainly in the Answer Slate, Kuridala Formation, and Staveley Formation. These bodies are most extensive in the east, where they form prominent ridges, and are known as 'Selwyn ironstones'. Some base-metal mineralisation, mostly Cu, is associated with the quartz-hematite bodies in places, and also occurs in black slate bands within the Answer Slate and Kuridala Formation. Areas of potential mineralisation are being explored by several mining companies.

SELWYN 1:100 000 SHEET AREA (Fig. M16)

by D.H. Blake

In the Selwyn Sheet area the oldest rocks exposed are regionally metamorphosed sedimentary and minor volcanic rocks mapped as undivided Soldiers Cap Group, Kuridala Formation, and Corella Formation. These units are intruded by granite and by numerous dykes, sills, and pod-like bodies of amphibolite and metadolerite, and they have been involved in two main phases of deformation: an early phase of tight to isoclinal folding and a later phase of more open folds. Bedding, cleavage, and foliation trends are mainly north-south, dips are generally steep to vertical, and minor folds with steep to gentle plunges are common.

Soldiers Cap Group rocks crop out in the east and southeast, and consist largely of medium to coarse micaceous and locally porphyroblastic schist and quartzo-feldspathic gneiss which probably represents metamorphosed greywacke-type rocks. Some schist and gneiss contain sillimanite. Also

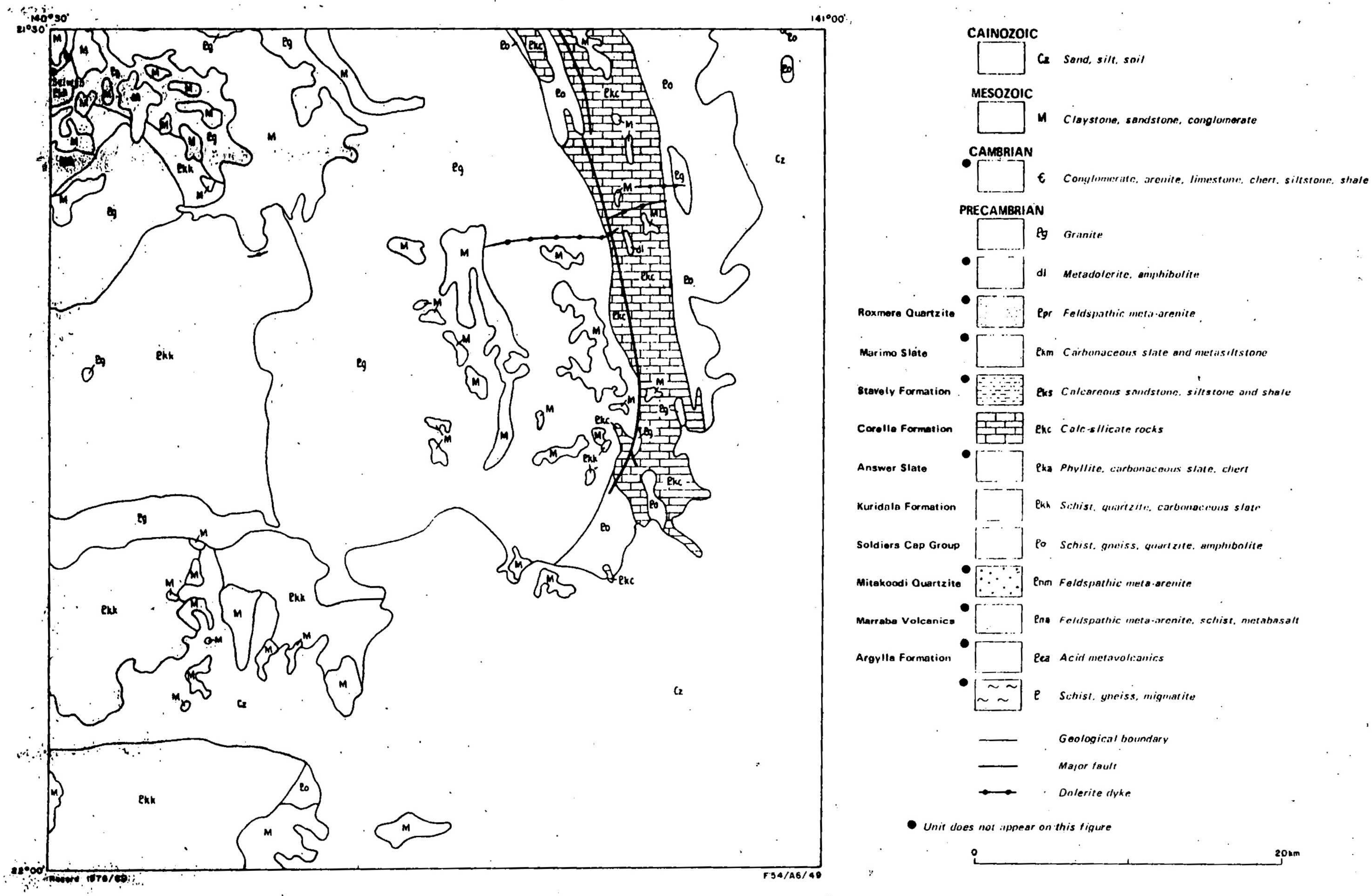

Fig M16 General geology, Selwyn 1:100 000 Sheet area present are quartzite which is locally garnetiferous, feldspathic to micaceous meta-arenite, migmatite, basic lava and tuff metamorphosed to patchily garnetiferous amphibolite, and minor banded iron formation, banded and brecciated calc-silicate rocks, and chert. Concordant to cross-cutting veins of quartz-feldspar pegmatite containing tourmaline and/or muscovite abound, as also do apparently concordant intrusive amphibolite bodies. The banded iron formation appears to be confined to a single stratigraphic level within the sequence. Several partly fault-bounded belts of Soldiers Cap-type rocks are present in areas previously mapped as Corella Formation.

The Kuridala Formation, like the Soldiers Cap Group, appears to consist mainly of metamorphosed greywacke-type sediments. These are represented by thin- to thick-bedded, medium to fine schist and micaceous meta-arenite which commonly contain porphyroblastic andalusite, garnet, and/or cordierite(?) Other rock types present are carbonaceous black slate and siltstone, in places containing andalusite porphyroblasts; feldspathic meta-arenite; quartzite, some of which forms prominent marker beds; and minor banded chert and banded and brecciated calc-silicate rocks. Sill- and dyke-like bodies of intrusive massive to schistose amphibolite are common.

Near the southern margin of the Sheet area the Kuridala Formation grades eastwards into typical Soldiers Cap schist and gneiss, indicating that the two units are probably stratigraphic equivalents.

The Corella Formation crops out in the northeast, mainly to the west of the Soldiers Cap rocks. It consists largely of thin-banded to brecciated calc-silicate rocks which range from siliceous to feldspathic to amphibolitic to richly calcareous (marble). Minor rock types present are quartzite, mica schist, metarhyolite, and metabasalt. Pod-like intrusions of metadolerite are common. Some calc-silicate breccia may have been formed by diagenetic processes, some may be due to penecontemporaneous slumping and some is undoubtedly tectonic, being formed during faulting, thrusting, and/or tight folding. Calc-silicate breccia is invariably present at contacts between Corella and Soldiers Cap rocks, but no good evidence was found to indicate an unconformity between these two units. Both units contain calc-silicate rocks and mica schist, they appear to interfinger with each other and to be of similar metamorphic grade, and they have been affected by the same two main phases of deformation. Hence they may be part of a conformable stratigraphic sequence rather than being separated by a major unconformity, as suggested previously. Which is the older of the two units has not been determined either in this area or in the adjoining Mount Angelay Sheet area to the north.

Two main types of granite are exposed. One consists of white to buff, fine- to coarse-grained and pegmatitic, heterogeneous leucogranite which is commonly foliated. It intrudes Corella and Soldiers Cap rocks, forming mainly small and highly irregular bodies. The other type is a pink, medium to coarse homogeneous biotite granite which commonly contains abundant euhedral to subhedral feldspar megacrysts. It is rarely foliated, forms both large and small plutons, and appears to be post-tectonic, as it cuts both bedding and foliation in adjacent Soldiers Cap, Kuridala, and Corella rocks. Intrusive contacts are generally sharp and clear-cut, although veins of pegmatite and apparently associated muscovite granite are locally common in adjacent country rocks. Hornfels is rarely present at granite contacts.

Several relatively young, non-metamorphosed, east-trending dolerite dykes intrude granite and other rocks. They are overlain by Mesozoic sediments, which form extensive mesa cappings in the northern part of the area. Many mesa cappings, in particular those towards the north, consist of weathered Precambrian rocks, especially granite.

The area is being actively explored by companies for base metals, in particular those parts containing outcrops of banded iron formation (Soldiers Cap Group) and carbonaceous black slate and siltstone (Kuridala Formation).

MOUNT ANGELAY 1:100 000 SHEET AREA (Fig. M17) by P.J.T. Donchak

The oldest unit in the Mount Angelay Sheet area is possibly the Soldiers Cap Group, which crops out in the east. It consists of interbedded quartzite; micaceous meta-arenite; coarse quartz-feldspar-muscovite-biotite schist and gneiss which commonly contain porphyroblastic garnet, andalusite,

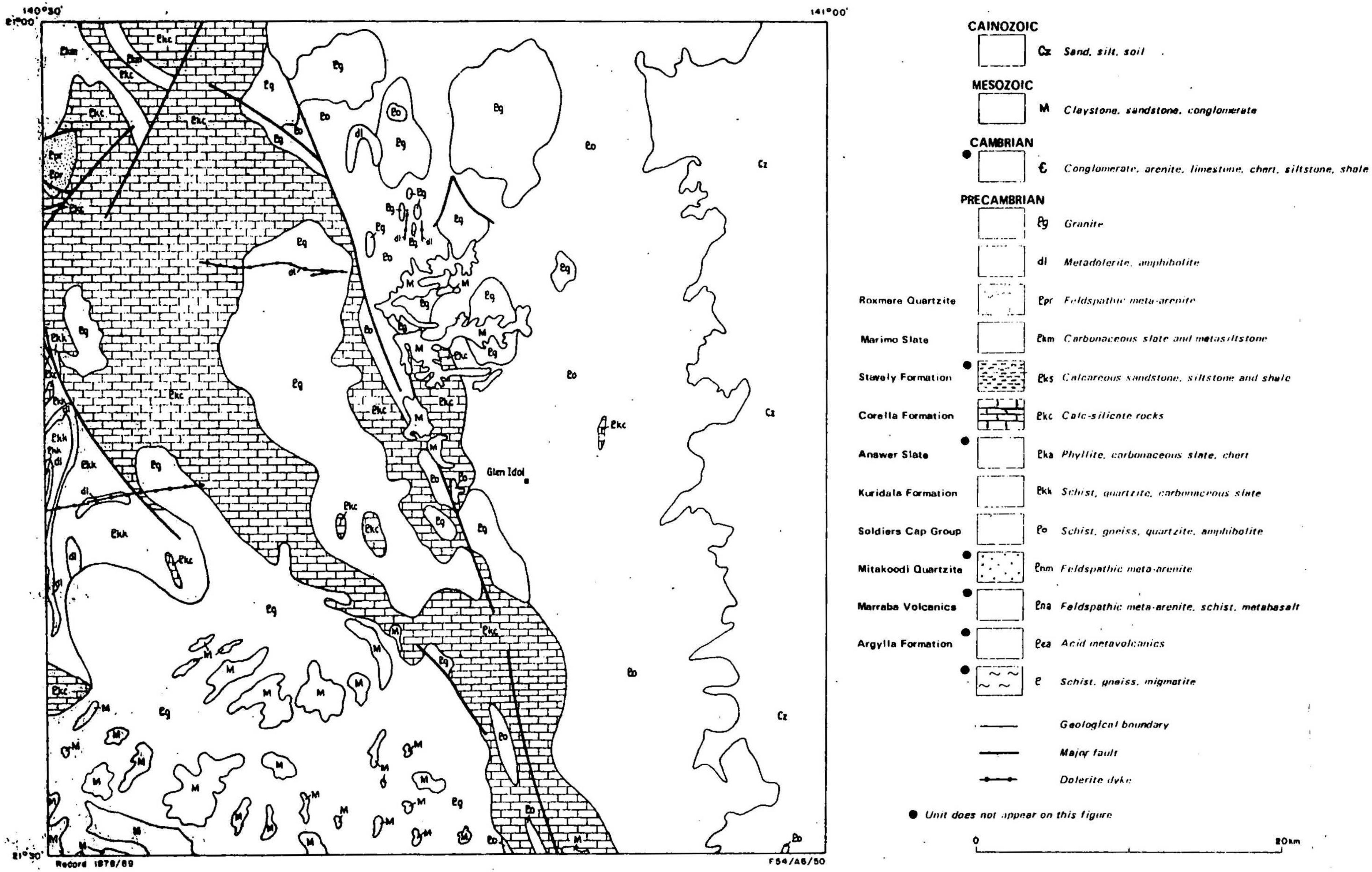

Fig M17 General geology, Mount Angelay 1:100 000 Sheet area sillimanite, cordierite(?), and staurolite; amphibolitic and locally garnetiferous metabasalt and metadolerite; para-amphibolite; minor thin-banded and brecciated calc-silicate rocks and banded iron formation; and numerous muscovite- and tourmaline-bearing pegmatite veins which in places are strongly boudinaged. Original sedimentary structures are generally obscured by regional metamorphic effects except in the far north, where some cross-bedding is recognisable. Rarely observed small-scale first-generation folds are isoclinal, trend north-south, and have sub-horizontal axes. Larger-scale second-generation folds are developed locally. They are open to tight, with steeply dipping axes plunging north-northeast, and in places have an associated axial-planar crenulation cleavage.

The Soldiers Cap Group passes westward into the Corella Formation. At the boundary, which is generally faulted and partly obscured by granite, the Corella Formation typically consists of metamorphosed breccia formed entirely of calc-silicate rocks. The metamorphism post-dates the brecciation. In places the boundary appears transitional rather than sharp, as lenses of massive, laminated, and brecciated calc-silicate rocks occur locally within the Soldiers Cap Group near the boundary, and in the south typical Soldiers Cap rocks interfinger with Corella calc-silicate rocks. No evidence for an unconformity was observed. Calc-silicate breccia, which may be in part tectonic and in part sedimentary, is the main rock type of the Corella Formation, although banded calc-silicate rocks are almost as common. There are also several small lenses of black carbonaceous slate, some containing copper and molybdenum mineralisation, and one small lens of quartz-feldspar-muscovite schist.

An apparently less metamorphosed sequence mapped as Corella Formation crops out in the northwest, and is generally fault-bounded to the east. It consists of cross-bedded siliceous, calcareous, and hematitic arenite and siltstone, breccia, and minor calc-silicate granofels. Both halite casts and 'matchstick' scapolite are common in this sequence. Most fragments in the breccia are of siliceous and calcareous arenite, but there also appear to be some basic volcanic clasts. Much of the arenite in this unit appears identical with that mapped as Staveley Formation in the Mount Merlin Sheet area.

Like the Soldiers Cap Group, the Corella Formation has undergone at least two major phases of folding. Most folds observed are open to tight second-generation structures with north-trending axes.

In the west the Corella Formation is in contact with three different formations, the Kuridala Formation in the south, and the Marimo Slate and Roxmere Quartzite in the north.

The Kuridala Formation is mainly faulted against the Corella Formation, and as no facing evidence was observed, its relative age could not be determined. It consists of fine-grained quartz-feldspar-muscovite schist locally containing biotite, garnet, and staurolite, together with micaceous meta-arenite, carbonaceous slate, and minor calc-silicate rocks and banded ironstone. Numerous metadolerite sills predating the main deformation occur near Kuridala, where they define a basinal structure. Later metadolerite intrusions cut across this structure. Cleavage formed during a first-generation folding event has been folded about north-trending axes of a second event.

The Marimo Slate crops out in the northwest, where it consists of carbonaceous and locally pyritic slate and metasiltstone and minor bands of chert and cross-bedded hematitic meta-arenite. It is generally extensively ferruginised near the Corella Formation. The boundary between the two units appears to be gradational where not faulted, and in contact zones both units contain beds of similar hematitic meta-arenite. The arenite beds generally young westward, indicating that the Marimo Slate probably overlies the Corella Formation; however, some reverse facings have also been found.

The Roxmere Quartzite consists of cross-bedded, locally micaceous, feldspathic meta-arenite. It is faulted against Marimo Slate to the north, and overlies Corella Formation to the east and south.

The main granite in the area is a coarse-grained, partly porphyritic, non-foliated, biotite-bearing type which forms a large batholith intruding all formations exposed in the south, where it is capped in places by Mesozoic sediments. This granite also appears to intrude irregular bodies of partly foliated leucogranite present along the boundary between the Corella Formation and Soldiers Cap Group. Small plutons of medium-grained, partly foliated and locally porphyritic hornblende granite intrude Corella Formation and Soldiers Cap Group in the north. Contacts between granite and country rocks range from lit-par-lit type to sharply discordant.

Metadolerite bodies intrude the Soldiers Cap Group and the Corella and Kuridala Formations. Some metadolerite clearly predates first-generation folding, but some is demonstrably younger. There are also two younger east-west dykes of non-metamorphosed dolerite that intrude granite.

Most of the base-metal mineralisation known in the Sheet area is associated with black carbonaceous slate in the Kuridala and Corella Formations and the Marimo Slate. Some occurs in banded iron formation within the Soldiers Cap Group near Glen Idol.

ARDMORE 1:100 000 SHEET AREA (Fig. M18) by R.J. Bultitude

The Precambrian rocks in the Ardmore 1:100 000 Sheet area can be broadly divided into three northerly-trending belts, each containing abundant metabasalt. The central and western belts are characterised by a lack of distinctive marker units that can be confidently correlated with units mapped elsewhere in the Mount Isa region.

The oldest rocks of the eastern belt are poorly exposed felsic volcanics, mainly tuff, of the Bottletree formation, at the base of the Haslingden Group. These are conformably overlain by greywacke conglomerate and pebbly meta-arenite of the Yappo formation. The pebbles in this formation are mainly of extensively recrystallised felsic volcanics. The Yappo formation is conformably overlain by quartzose, feldspathic, and sericitic meta-arenites of the Mount Guide Quartzite, a unit that has been folded about north-trending axes, and intruded by numerous metadolerite dykes. The Mount Guide Quartzite is overlain, apparently conformably, by the Eastern Creek Volcanics, a sequence of essentially non-schistose, extensively epidotised, amygdaloidal metabasalt lava flows and intercalated lenses of tuffaceous(?)

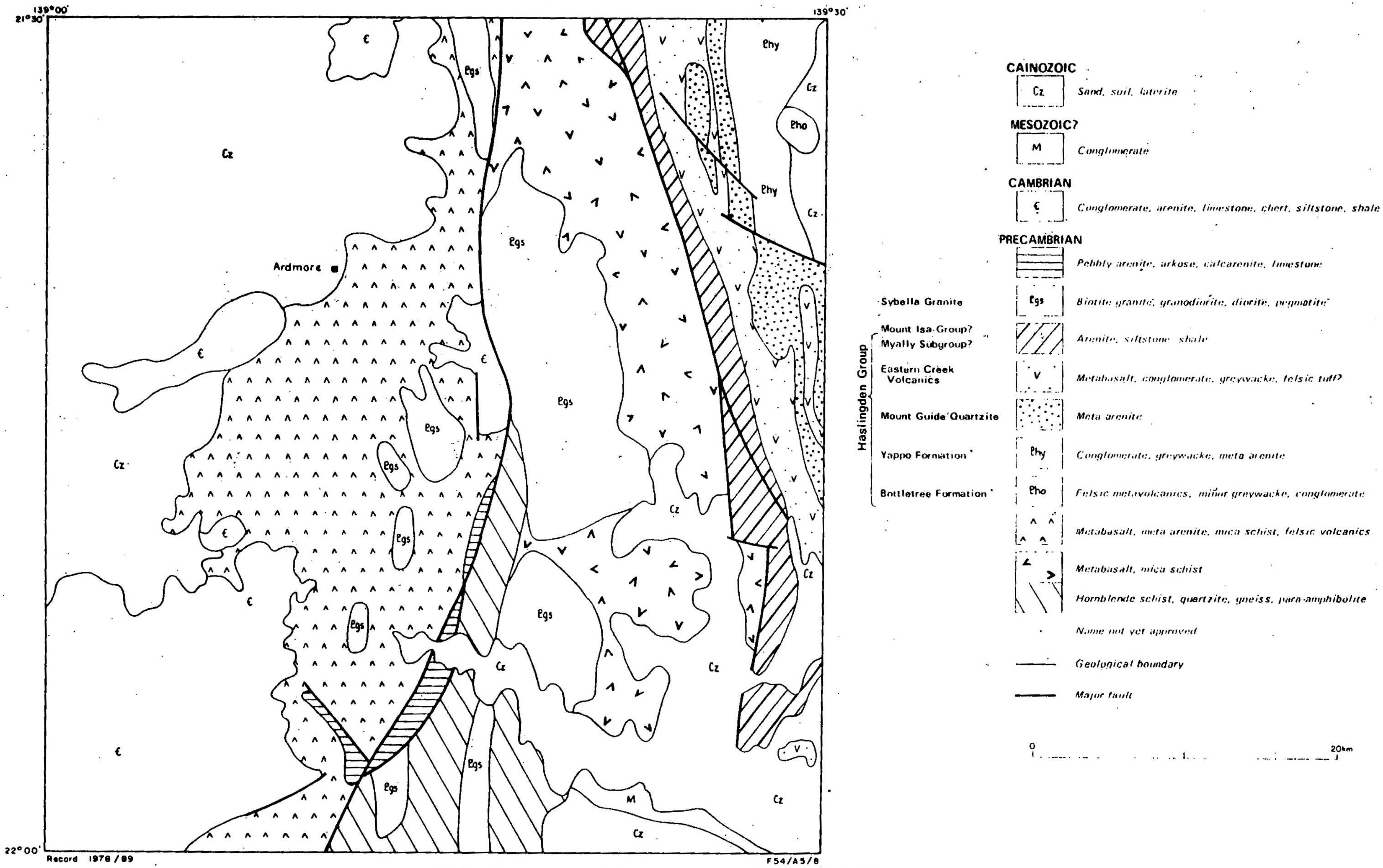

Fig M18 General geology, Ardmore 1:100 000 Sheet area greywacke conglomerate, pebbly greywacke, and grey to pink quartzitic rock which may represent felsic tuff. Most clasts in the conglomeratic rocks are of metabasalt, similar to that of adjacent lava flows, and little-altered felsic volcanics. The formation also includes rare lava flows or small intrusions of dacitic porphyry containing abundant biotite. It is intruded by numerous amphibolitic metadolerite dykes, and is overlain, apparently concordantly, by a sequence consisting mainly of pyritic, sericitic, feldspathic, and quartzose arenite, tentatively assigned to the Myally Subgroup. These arenites appear to grade upwards into poorly exposed dolomite and pyritic siltstone and shale which may be correlatives of the Moondarra Siltstone and Breakaway Shale of the Mount Isa Group. Rocks younger than the Eastern Creek Volcanics are not intruded by metadolerite dykes.

The central belt is bounded to the east and west by faults. In the east it consists of schistose, amygdaloidal and massive, amphibolitic metabasalt and subordinate lenses of sericitic, feldspathic, and quartzose meta-arenite, para-amphibolite, and biotite-muscovite schist, some of which contains cordierite. These rocks are intruded by metadolerite dykes, pegmatite veins, rare quartz-feldspar porphyry dykes, and granite. In the southwest, interlayered hornblende schist, feldspathic, micaceous and glassy quartzite, augen gneiss, para-amphibolite, minor garnetiferous calc-silicate gneiss and schistose amygdaloidal metabasalt, and numerous extensively deformed pegmatite veins are intruded by granite, by probably related undeformed pegmatite veins, and also by a few dykes of little-altered dolerite containing primary biotite. Mainly hornblende schist (metabasalt) and interlayered mica schist are present to the north. The metamorphic grade in this central belt increases westwards from about middle greenschist facies to probably at least middle amphibolite facies. The metamorphism does not appear to be directly related to granite intrusion. The rocks here were originally mapped as Eastern Creek Volcanics, but may form part of an older sequence.

In the western belt, in the far south, little-metamorphosed basalt, similar to that in the eastern belt, with intercalated arenite and siltstone, is overlain, possibly unconformably, by pebbly quartzose arenite, arkose, calcarenite, and limestone, which are preserved in small partly fault-bounded synclines. To the north schistose metabasalt is interlayered with recrystallised felsic tuff and schistose tuffaceous metasediments. South and southeast of Ardmore homestead these schistose rocks are extensively intruded by pegmatite dykes and mostly non-foliated biotite-muscovite leucogranite. The central and northern parts of the western belt consist mainly of hornblende schist, mica schist which in places contains andalusite, schistose amygdaloidal metabasalt, and minor gneissic felsic volcanics. Regional metamorphism in the belt increases from lower-greenschist facies in the south to about middle-amphibolite facies in the central and northern parts.

Granitic rocks are restricted to the central and western belts, and are mapped as Sybella Granite. At least six different phases are present, the general order of intrusion being from relatively mafic to relatively felsic. The main phase, a non-foliated to weakly foliated, coarse-grained, xenolithic, porphyritic biotite granite, intrudes small masses of medium-grained biotite-rich granodiorite, strongly foliated gneissic granite, and minor xenolithic diorite. These phases are cut by veins and small bodies of foliated, medium-grained, biotite granite and biotite leucogranite. Another phase, exposed south and southeast of Ardmore homestead, consists of non-foliated, medium- to coarse-grained and pegmatitic muscovite and biotite-muscovite leucogranite. Each of these phases is cut by undeformed quartz-feldspar pegmatite that commonly contains muscovite, less commonly tourmaline. In most places bedding and foliation in adjacent country rocks show little apparent disruption, and marked thermal metamorphic effects are generally restricted to within a metre or so of granite contacts. The youngest intrusions in the area are a few non-metamorphosed, chalcopyrite-bearing dolerite dykes which cut Sybella Granite.

Minor copper mineralisation occurs in metabasalt and in quartz veins cutting metabasalt. There are no large mines, operating or abandoned, in the Sheet area.

OBAN 1:100 000 SHEET AREA by C.M. Mock

The Oban 1:100 000 map (preliminary edition) was issued during the year. Record 1978/87, 'Geology of the Oban 1:100 000 Sheet area, northwestern Queensland: Progress report' is with the editors. The following changes have been made to stratigraphic nomenclature used on the Urandangi 1:250 000 geological map:

1) The lower part of the Mount Guide Quartzite is now mapped as Yappo formation (shown on the Oban preliminary edition as Malbon Vale Formation).

2) The Eastern Creek Volcanics east of the Mount Isa Fault are subdivided into three members, as in the northerly adjacent Mount Isa 1:100 000 Sheet area.

3) The Carters Bore Rhyolite is distinguished in the northern part of the Sheet area.

4) The Mount Isa Group is subdivided into the Warrina Park Quartzite, Moondarra Siltstone, and Breakaway Shale.

In the Oban Sheet area a narrow westerly belt of medium to high-grade contact-metamorphosed, multiply-folded Haslingden Group rocks, in contact with the Sybella Granite, is thrust up against a wider easterly belt of low-grade regionally metamorphosed Haslingden and Mount Isa Group rocks. Three major metamorphic events are inferred: a regional metamorphism culminating in intrusion of Sybella Granite at about 1750 m.y.; a contact metamorphism to upper amphibolite grade produced in rocks intruded by the Sybella Granite at intermediate to deep crustal levels; and a subsequent low-grade moderate-pressure regional-metamorphic event which was responsible for the deformation and foliation of the Sybella Granite.

GEORGETOWN PROJECT

by

J.H.C. Bain, D.E. Mackenzie, B.S. Oversby, and I.W. Withnall

STAFF: J.H.C. Bain[1], (Project Leader), B.S. Oversby[1], D.E. Mackenzie[1], I.W. Withnall[1] Geological Survey of Queensland (GSQ), E.M. Baker[1] (GSQ)*, A.G. Rossiter[2], P.A. Scott[2*], L.P. Black[3*], I.C. O'Donnell[4],

Geophysicists W. Anfiloff, M. Idnurm, and J.W. Giddings worked with the party part-time.

[1]Geology, [2]Geochemistry, [3]Geochronology, [4]Drafting.

*Part time.

AIMS: To revise and extend geological knowledge of the Georgetown Inlier, in particular to make more accurate and detailed geological maps; to investigate and determine the regional geochemical and geophysical patterns, to determine the distribution, physical and chemical nature, source, and controls of the mineral deposits; to re-assess the mineral resources and potential of the region; and to stimulate and assist mineral exploration there.

FIELD ACTIVITIES

In May and June Withnall set up and supervised drilling by the Queensland Mines Departments 'Longyear 34' drilling rig (including bulldozing of about 50 km of tracks), carried out detailed ground traverses (with chip sampling) along the proposed drill sections, and measured in detail a type section of the 'Candlow Formation'.

During July and August, Mackenzie and Withnall logged drill core, examined in detail type sections of the 'Yarman', 'Malacura', Langdon River, 'Candlow', and 'Heliman' Formations, the 'Dismal Creek Volcanics', and the 'Maureen Volcanics'. They also re-examined or checked several problematical areas of earlier work on the North Head, Forest Home, Esmeralda, and Abingdon Downs 1:100 000 Sheet areas; Withnall and Bain undertook similar work on parts of the Forest Home, Forsayth, and Gilberton 1:100 000 Sheet areas. Withnall recognised and delineated a new stratigraphic unit ('Townley Formation') in the Etheridge Group; it consists of phyllite, phyllitic siltstone, and quartzose siltstone and sandstone, and was previously included partly in the overlying 'Heliman Formation' and partly in the 'Robertson River Formation'. Mackenzie examined and sampled many outcrops of 'Forest Home Granodiorite', revised the 1977 field season maps of the 'Dismal Creek Volcanics' (Mount Darcy area) and the area to the northwest and west (NW Forest Home 1:100 000), and extended and refined knowledge of the geology around the 'Maureen' U-F-Mo deposit (NE corner Forest Home, SE corner Abingdon Downs 1:100 000 Sheet areas). Oversby re-examined Newcastle Range Volcanics in the Fish Hole (Robertson River) area, and the relationships between the rhyolitic and basaltic lavas in the northeastern part of the Agate Creek Volcanics.

All personnel participated in a six-day safari-type field conference in the central part of the Georgetown Inlier in August. This conference was designed to give other geologists, principally mineral exploration company staff, an opportunity to examine the area in company with the BMR and GSQ geologists who have recently re-mapped the area as part of the Georgetown Project field research. The excursion was held in conjunction with the Third Australian Geological Convention of the Geological Society of Australia. Twenty-seven geologists from fourteen companies, two State Surveys, and BMR attended.

DRILLING

The objectives of the stratigraphic drilling program were to provide data on the lithology of the 'Candlow Formation', and on its relationships with the better-exposed underlying and overlying units, and to assess its economic potential. The 'Candlow Formation' appears to be of moderately shallow-water origin, contains a significant proportion of pyritic carbonaceous rocks (cf. Soldiers Cap Group, Mount Isa) and gossanous outcrops, and has been a target for base-metal and uranium exploration.

A total of 1500 m (max.) of drilling was planned, including at least 1200 m through the 'Candlow Formation'; the remainder was to assess the nature of the contacts with the overlying Langdon River Formation and the underlying 'Heliman Formation'. Seven holes, averaging about 200 m each, were planned - one for each contact, one each through the Stockyard Creek Siltstone Member and the 'White Bull Member', and one in each of the three subdivisions of the Formation. All holes were angled at 45^{o}, and aligned normal to the strike of the near-vertical lithological layering.

The drill sites were located on and near a track between East Candlow Dam and White Bull Bore, 150 km by road and track southwest from Georgetown (metric G.R. 165337, North Head 1:100 000). This area was chosen for the relative thinness of the 'Candlow Formation' and access to water.

Severe drilling problems prevented some of the holes from reaching target depth. The first, through the base of the Langdon River Formation, reached 99.15 m* in intensely sheared rocks. Rocks intersected were maroon and dark grey banded phyllitic siltstone and black carbonaceous phyllitic siltstone, all variably weathered.

A hole in the uppermost part of the 'Candlow Formation' intersected variably carbonaceous quartz-lithic fine sandstone and siltstone, and black carbonaceous siltstone. Primary pyrite (sparsely disseminated and as scattered veinlets) was intersected at 120 m, pervasive weathering having extended to over 100 m down-hole.

The third hole intersected 108 m of cleaved sericitic sandstone, quartz-lithic and carbonaceous siltstone, and minor shale of the 'Candlow Formation', then entered black pyritic (up to 3-5%) carbonaceous siltstone and minor white fine quartzose sandstone (Stockyard Creek Siltstone Member). It was abandoned in crushed carbonaceous siltstone at 210 m.

The fourth hole, drilled into the middle 'Candlow Formation' immediately below the Stockyard Creek Siltstone Member, intersected 142 m of interbedded, commonly pyritic and locally dolomitic, weakly to moderately carbonaceous siltstone and fine quartzose sandstone; weathering extended to about 30 m.

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* All depths are down-hole

The fifth hole, from the lower part of the middle 'Candlow Formation' into the 'White Bull Member', was terminated in crushed rock at about 152 m. The sixth hole, from the lowermost 150 m of the 'Candlow Formation' into the Heliman Formation, was stopped at 182 m. At the time of writing, no lithological data were available on these last two holes.

GEOLOGY OF THE MAUREEN U-F-Mo PROSPECT AREA (Figs M19 and M20)

The Maureen uranium prospect is located in basal sediments in the northeastern extremity of the'Maureen Volcanics', a late Palaeozoic sequence of acid and minor basic volcanic and associated sedimentary rocks, about 35 km north-northwest of Georgetown.

The volcanics rest on a basement of middle Proterozoic schist, gneiss, quartzite, amphibolite, and migmatite ('Robertson River Formation', schist phase) cut by numerous small bodies of granite, leucogranite, and pegmatite.

The lowermost beds of the 'Maureen Volcanics' are coarse to fine-grained micaceous and/or quartzose sandstone, arkosic and tuffaceous sandstone, conglomerate, siltstone, and minor shale, tuff, and rhyolite, and are up to 200 m thick. This sequence thins considerably over a short distance to the north, and more gradually to the south. It is overlain by about 100-150 m of flow-banded rhyolite - variably brecciated glassy rhyolite probably extruded subaqueously, minor rhyolitic tuff, and fine, micaceous sandstone. This unit complements the one below, thickening as the lower one thins. A wedge of brecciated glassy rhyolite, rhyolitic agglomerate, and rhyolitic ignimbrite or agglomerate in the north of the area is similar to both the underlying and overlying rocks.

Above the rhyolite layers is a complex sequence, up to 170 m thick, of quartzose, micaceous, and tuffaceous(?) sandstone and minor siltstone with common intercalated rhyolite and rhyolitic agglomerate. This upper sedimentary unit, like the basal unit, thickens markedly near Fiery Creek, and in the north appears to have overlapped underlying units to rest directly on basement.

In the south of the area, the upper sediments are overlain and possibly, in places, intruded by an aphanitic basalt or basic andesite. The basalt/andesite is partly intrusive into the overlying units - 200 m of rhyolitic tuff and ash (unwelded to densely welded), agglomerate, and ignimbrite, with minor tuffaceous sediments at the base. Above this unit is about 100 m of flow-banded rhyolite, which may be intrusive at its northern extremity, and a second basalt/basic andesite unit, up to 100 m or more thick, which in the north directly overlies the upper sediments.

Deposition and emplacement of these rocks was followed, apparently after a substantial hiatus, by emplacement and eruption of a massive rhyolitic agglomerate containing large blocks of a wide range of metamorphic and other volcanic rocks. The agglomerate is partly intrusive, cutting the upper sediments and the flow-banded rhyolite, and partly concordant. It thins northwards, and gives way to an extensive blanket of rhyolitic ignimbrite, agglomerate, breccia, and minor lava to the north and west. The volcanic sequence at Maureen is completed by a thin layer of dacitic ignimbrite, and is capped by remnants of late Jurassic to Tertiary sandstone, ferricrete, and laterite with deep-weathering profiles.

Closely spaced east-west faults and lineaments are a marked feature of the area; they appear to be mostly reactivated pre-volcanic structures. Some have been active during volcanism and sedimentation (fault near Camp Oven Creek, and fault-lineament system on the northern side of Fiery Creek), and have had a profound effect on thickness and distribution of stratigraphic units. The Camp Oven Creek fault appears to have acted as a bounding structure early in the volcanic episode, was overlapped at a later stage, and was then reactivated to cut the upper ignimbrite and agglomerate. The fracture-lineament system near Fiery Creek has been the locus of thickening of some units, truncation of others, and the emplacement of intrusive bodies, and has also provided channelways for the fluids that formed the main U-F-Mo deposits at Maureen. Numerous other east-west basement fractures and lineaments appear to have been propagated upwards into the volcanic sequence, and in two places in the basal sediments are known to be the loci of minor uranium deposits; many, if not all, of the fractures may thus contain uranium mineralisation.

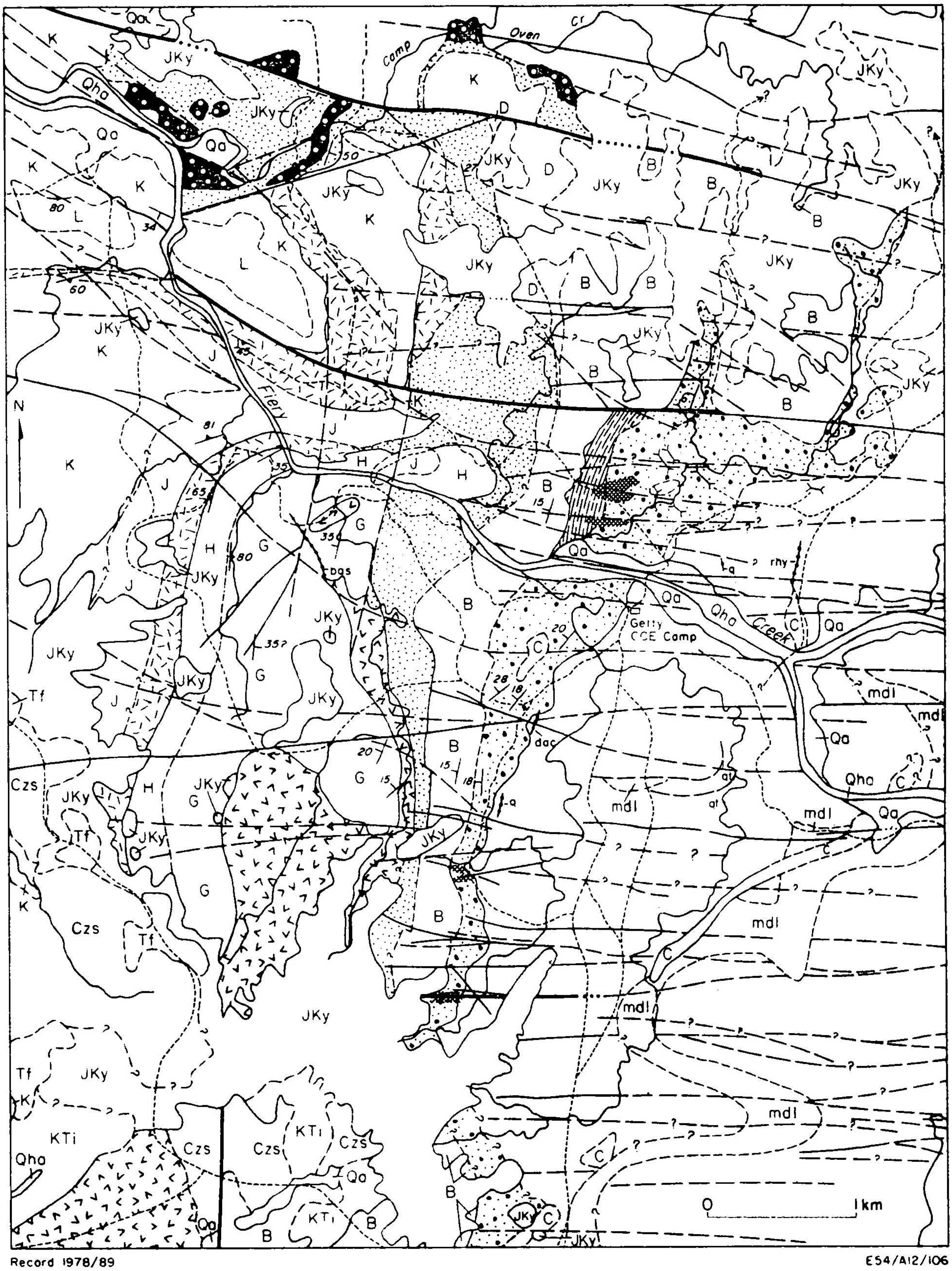

Fig M19 Geology of the Maureen area

CAINOZOIC	Holocene		Qha	*Active alluvium, mainly sand*
	Quaternary		Qa	*Inactive alluvium, soil*
	Cainozoic		Czs	*Sand, soil, alluvium*
	Tertiary		Tf	*Nodular ferricrete, laterite, deep weathered horizons*
MESOZOIC	Late Cretaceous to Tertiary	Bulimba Fm	KTi	*Immature kaolinitic, siliceous, or ferruginous quartz sandstone and conglomerate*
	Late Jurassic to early Cretaceous	Yappar Member (Gilbert River Fm)	JKy	*Mature to supermature kaolinitic quartz sandstone and conglomerate*
UPPER PALAEOZOIC	Carboniferous (-Permian ?)	"Maureen Volcanics"	L	*Dacitic ignimbrite; some agglomerate. Hornblende phenocrysts*
			K	*Rhyolitic ignimbrite and agglomerate; some rhyolite and rhyolite breccia*
			J	*Massive, very coarse-grained polymict rhyolitic agglomerate; intrusive in part*
				Fine-grained aphanitic basalt or andesite
			H	*Strongly flow-banded/laminated porphyritic rhyolite*
			G	*Rhyolitic tuff, ash, agglomerate, minor ignimbrite; minor tuffaceous sandstone*
				Fine-grained aphanitic basalt/andesite
				Quartz, micaceous, quartz-lithic, and quartzo-feldspathic sandstones; siltstone; rhyolite. Flow-banded rhyolite, rhyolitic agglomerate
			D	*Brecciated glassy rhyolite rhyolite agglomerate, rhyolitic agglomerate or ignimbrite*
			C	*Unassigned rhyolites mainly intrusive*
			B	*Flow-banded rhyolite, variably brecciated glassy rhyolite, minor rhyolitic tuff*
				Med-coarse-grained micaceous quartz sandstone, quartzo-feldspathic sandstone, conglomerate, siltstone, shale; minor rhyolite, rhyolitic tuff. Fine micaceous sandstone
PROTEROZOIC			mdl	*Metadolerite, amphibolite, metagabbro*
		Robertson River Fm (schist phase)		*Schist, gneiss, quartzite, migmatite*

Symbol	Description
	Geological boundary, position accurate
	Geological boundary, position approximate
?	*Geological boundary, position doubtful*
	Fault, position accurate
	Fault, position approximate, or doubtful
	Fault, concealed
	Trend (of bedding) line; qt-quartzite
	Lineament, clearly defined
	Lineament, less clearly defined
?	*Lineament, obscure or doubtful*
	Dyke: qt-quartzite, bas-basalt, dac-dacite, rhy-rhyolite
20	*Dip and strike of bedding*
80	*Dip and strike of igneous layering/banding*
	Areas of Uranium mineralisation (approximate)
	Costean
	Road, track
	Stream

Record 1978/89

E54/A12/106A

Fig M20 Reference for Fig M19

GEOPHYSICS

Newcastle Range magnetic stratigraphy

Giddings and Idnurm collected stratigraphically-controlled specimens of Newcastle Range Volcanics in the Shrimp Creek area of the eastern Newcastle Range, and the Fish Hole area of the main range (Mount Surprise and Forsayth 1:100 000 Sheet areas, respectively). Rocks in the two areas apparently belong to two separate stratigraphic sequences, which are structurally juxtaposed and whose relative ages are not known. Ages are too similar for differences to be resolved by isotopic dating. The investigation by Giddings and Idnurm is designed to establish magnetic stratigraphies for the two sequences, if possible; this may permit relative ages to be established, and so clarify original relationships between the sequences. Results are not yet available.

Agate Creek gravity

Anfiloff undertook a detailed gravity traverse of about 20 km across, and beyond, the northwestern part of the Agate Creek Volcanic's outcrop area (Gilberton 1:100 000 Sheet area) designed to investigate the subsurface morphology of the unit. The outcrop area has the form of a shallow northwest-trending basin at the present level of exposure, but it is possible that its form at depth could be different. There is probably sufficient density contrast between mafic lavas in the unit and underlying Robin Hood Granodiorite for the form of the contact between the two to be inferred from the detailed gravity data. Results are not yet available.

OFFICE ACTIVITIES

Much of the office activity was directed towards preparing three major review papers to be included in a projected volume on 'The Geology and Geophysics of Northeastern Australia' edited by R.A. Henderson and P.J. Stephenson, and to be published by the Geological Society of Australia. The main conclusions of these reviews are reported below:

LATE PALAEOZOIC CONTINENTAL VOLCANISM IN NORTHEAST QUEENSLAND, by B.S. Oversby, L.P. Black, & J.W. Sheraton.

(1) The Newcastle Range Volcanics are one remnant of an extensive late Palaeozoic ignimbrite-dominated 'Newcastle Range-Featherbed' volcanic field, centred in the Georgetown-Chillagoe district; volcanic sequences of similar age in northern Cape York, in the Townsville-Charters Towers district, and in the Bowen area, are believed to represent separate but overlapping fields;

(2) the stratigraphic framework of 'Newcastle Range-Featherbed' field rocks, established by regional reconnaissance in the late 1950's and early 60's, is inherently artificial because it is based on present geographical location and extent of outcrop areas; a 'natural' framework in which rocks from common eruptive centres were grouped together would be more informative;

(3) major remnants of the field, such as Newcastle Range and Featherbed Volcanics, are believed to coincide closely with first-order volcano-tectonic subsidence structures; a wide variety of subsidiary second-order features (basins, troughs, cauldron subsidence structures, etc.) occur within postulated volcano-tectonic subsidences. This hierarchy of inter-related volcanic subsidence structures replaces the all-embracing 'cauldron subsidence areas' of earlier workers;

(4) voluminous ignimbrite eruptions in the 'Newcastle Range-Featherbed' field were apparently accompanied by progressive gentle subsidence, and not by caldera collapse; resurgence (updoming) involving the entire thickness of country rocks between a magma chamber and its volcanic superstructure does not seem to have occurred. These features are believed to be a function of the passive nature of magma ascent, which was accompanied by underground cauldron subsidence and stoping, and vertical segmentation of country rocks and volcanic sequences (especially the latter);

(5) ring-dykes and concordant intrusive bodies preceded ascending magma chambers in space and time; their emplacement at any particular level does not seem to record any special event during the continuum of magma ascent. Minor late-stage 'settling-in' faults are believed to have formed in response to adjustments made by volcanic piles to stabilisation, cooling, and solidification of underlying magma chambers;

(6) the late Palaeozoic volcanic fields of northeastern Queensland occurred in a postorogenic, 'Andean', setting; subduction may not, however, necessarily have been taking place when they formed.

THE PRECAMBRIAN GEOLOGY OF NORTHEAST QUEENSLAND, by I.W. Withnall[2], J.H.C. Bain, & M.J. Rubenach[4].

1. The Georgetown Inlier can be subdivided into three tectonic or litho-structural subprovinces; Croydon (western part of Inlier), Forsayth (central and greater part of inlier), and Paddy's Creek (easternmost part of Inlier). The last two are similar, but separated by a major 8-km wide mylonite zone of unknown age. The first is lithologically distinct, and overlies the Forsayth Subprovince with angular discordance.

2. Geological, structural, and geochronological studies indicate that the metamorphic rocks in both the Forsayth and Paddys Creek Subprovinces form continuous sequences (Etheridge Group in the former), and that there is no identifiable basement as formerly supposed.

3. A stratigraphic sequence has been established in the least-deformed rocks of the Forsayth Subprovince - but more detailed studies than have so far been attempted would be needed to determine whether existing rock-unit boundaries in areas of higher metamorphic grade and more intense folding represent spatial or temporal changes in lithofacies.

4. The metamorphic rocks in the Forsayth Subprovince have been deformed by five discrete episodes of folding, of which the first two were the most intense and associated with the main periods of metamorphism and granitoid emplacement during the middle Proterozoic (1570 m.y. and 1470 m.y.). The third and fourth events occurred at about 1000 m.y. and 400 m.y., respectively.

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[2] GSQ.

[4] James Cook University of North Queensland

5. The original (depositional) age of the rocks of the Georgetown and other Precambrian inliers is not known, although the Etheridge Group must be older than 1570 m.y. - the age of the first main deformation.

6. What was previously designated the Forsayth Batholith has been subdivided into at least five batholiths containing nineteen named units. Field relationships and some isotopic dating indicate a range of Proterozoic and Palaeozoic ages from about 1570 m.y. to possibly Siluro-Devonian (about 400 m.y.). Limited geochemical work indicates that many of these units are separate petrological suites, but additional work is necessary to determine the nature, distribution, and origin of all suites. Further isotopic dating is also necessary to relate their emplacement to the deformational/metamorphic events.

7. Rocks in the Dargalong, Yambo, and Coen Inliers to the north are very like and probably equivalents of those in the Georgetown inlier, but detailed studies of the structure, metamorphism, geochemistry, and geochronology are needed to confirm this.

MINERAL DEPOSITS OF THE GEORGETOWN REGION, QUEENSLAND, by J.H.C. Bain & I.W. Withnall[2]

1. Many or most of the copper and lead-zinc-copper deposits in the Einasleigh Metamorphics are apparently within or close to a single stratigraphic level, apparently stratabound, and probably syngenetic in origin. The last is indicated by the similarity in the form and mineralogy of the deposits and host rocks to those of better-known syngenetic stratabound deposits such as those in the Broken Hill district.

2. Much research remains to be carried out into:

(a) the stratigraphy and depositional environment of the Einasleigh Metamorphics;

(b) the distribution of all deposits with respect to the stratigraphy; and

(c) the nature of the deposits,

before the full potential of the Einasleigh Metamorphics for base metal deposits can be realistically assessed.

3. Stratabound zinc concentrations in the upper part of the Robertson River Formation are probably syngenetic; silver-lead veins at a similar stratigraphic level in this formation may be related, and may have formed by modification of stratabound deposits by Proterozoic metamorphism or late Palaeozoic hydrothermal events.

4. There are four main categories of gold-silver deposits;

(a) those associated with Proterozoic acid volcanics and comagmatic granites (e.g., Croydon);

(b) those associated with Proterozoic metabasic rocks in green-schist-grade metasediments (e.g., Gilberton);

(c) those associated with Proterozoic and/or Siluro-Devonian granitoids in amphibolite-grade schists (e.g., Forsayth);

(d) those associated with late Palaeozoic rhyolite dykes and breccia pipes (e.g., Kidston).

The first and second are probably of Proterozoic age, and the last is of undoubted late Palaeozoic age. The third is possibly of late Palaeozoic age, although Proterozoic geological features appear to be major controls of the nature and distribution of the deposits.

5. Uranium deposits, such as Maureen, characterised by various combinations of uranium, fluorine, and molybdenum, are common throughout the region, and are closely associated with the late Palaeozoic acid igneous rocks. The deposits are believed to be of mainly hydrothermal origin, and genetically related to extensive late Palaeozoic magmatism. Deposits are mostly localised near the late Palaeozoic surface in zones that had high porosity and permeability, and were linked with source regions by permeable channelways (commonly faults). Suitably porous and permeable access channels and deposition sites may have been of sedimentary, diagenetic, volcanic, hydrothermal, or tectonic origin; consequently deposits, although apparently generally small, are present throughout the region in a variety of host rocks. Structural suitability of sites appears to be the pre-eminent control of the primary hydrothermal deposits. Secondary (and sedimentary) deposits are less likely to be thus confined. The presence of Proterozoic anatectic granites with high uranium and thorium (monazite, etc.) contents suggests that a regional uranium anomaly existed in the area before the late Palaeozoic magmatic events which appear to have acted as a major concentrator of uranium, but may not have been a primary source of the element.

6. Two extensive very low-grade copper-molybdenum deposits - Mount Turner and Mount Darcy - near Georgetown are representatives of a class of deposit that may be more common than hitherto suspected within the region of late Palaeozoic acid igneous rocks. They consist of disseminated and veinlet sulphides in hydrothermally altered Proterozoic granitoids and metasediments, and late Palaeozoic granodiorite and rhyolite porphyries and breccia pipes. They are of the porphyry copper-molybdenum type, but apparently lack supergene enrichment zones. The Kidston breccia-pipe gold deposit is a related type.

7. Much additional research needs to be directed towards determining in detail the nature of typical examples of each class of deposit, including the various lithological, structural, and chemical controls and the relations between the deposits and their hosts, and with one another.

MAPS AND REPORTS

Mackenzie completed, checked, and revised 1:25 000-scale geological compilation sheets covering Forest Home, North Head, and parts of the Gilbert River and Esmeralda 1:100 000 Sheet areas, and made preparations for their release as field compilations and the production of preliminary-edition 1:100 000 geological sheets. This work involved additional airphoto interpretation and some petrographic studies.

Oversby and Withnall completed work on and had issued BMR Record 1978/44 - Geology of the Georgetown 1:100 000 Sheet area (7661), north Queensland, Part (a) (excluding Proterozoic granitoids).

A report on the mines and mineral deposits of the Georgetown 1:100 000 Sheet area by Withnall is in press as Geological Survey of Queensland Report 100.

A set of five maps sheets - Cu-Pb-Zn, Cu-Co-Ni, Sn-W-Nb, U-Ce-Th, and U-As-Bi for the Forsayth 1:100 000 Sheet area in the Australia 1:100 000 stream-sediment geochemistry series, and an accompanying explanatory text and interpretation of the data (BMR Record 1978/17 by Rossiter and Scott) were issued.

GEOCHRONOLOGY AND GEOCHEMISTRY

Results and progress with these aspects of the work are covered in the Metalliferous Laboratory report.

VOLCANOLOGY

STAFF: R.W. Johnson, R.J. Bultitude (part time), D.A. Wallace (part time), D.E. Mackenzie (part time)

INTRODUCTION by R.W. Johnson

Most of the year was spent in collecting, processing, and assessing petrological data from late Cainozoic volcanoes in northern Papua New Guinea.

Fifteen papers have been submitted for publication, or are in press, or were published, during the course of the year (several of these papers are co-authored by non-Bureau personnel, and four are abstracts of papers presented at geological symposia in Tokyo and Toronto). The collection of whole-rock chemical analyses for the project is virtually complete, and the principal objective is a final evaluation of the data and their integration into models for the late Cainozoic tectonic evolution of Papua New Guinea.

ORIGIN OF THE WILLAUMEZ-MANUS RISE, by R.W. Johnson

The Willaumez-Manus Rise is a 450 km-long, northwest-trending, submarine feature that divides the Bismarck Sea floor into two basins. Little attention has previously been given to the nature and origin of the rise, but as subaerial Quaternary volcanoes surmount its northwestern and southeastern ends, the feature has been studied (in conjunction with J.C. Mutter, Geophysical Branch) to determine its tectonic significance and its relationship to the volcanism.

The rise does not appear to be an extinct spreading axis, or a remnant arc, or a hot-spot trace. A preferred interpretation is that the rise is the raised edge of the basin to the west, and that it formed in response to a thermal anomaly beneath the eastern basin, which is younger than the western basin. This interpretation may have an important bearing on problems of magma genesis in this part of Papua New Guinea. The uplift may have triggered off diapirs that led to volcanism along parts of the rise.

VOLCANOES OVER THE NEW BRITAIN BENIOFF ZONE by R.W. Johnson

DATA CATALOGUE

Major- and trace-element analyses for 210 rocks from late Cainozoic volcanoes on New Britain and the Witu Islands have been compiled on magnetic tape and disc, and presented in 21 tables in a microfiche Report. Modal analyses (phenocryst abundances) and locality descriptions, including grid references, are also listed. Each sample is assigned an alphanumeric identification code that allows its chemical analysis to be found readily. The coding system is based on the grouping of New Britain and Witu Islands volcanoes into five zones which overlie different parts of the New Britain Benioff zone. This data compilation was made in collaboration with Dr B.W. Chappell of the Department of Geology, Australian National University (ANU).

Thirty-two rocks have also been analysed for rare-earth elements (REE), Cs, Pb, Th, U, and Hf by spark-source mass spectrography at the Research School of Earth Sciences, ANU, in collaboration with Dr S.R. Taylor. These data are not included in the microfiche Report, but will be presented and discussed in a paper at present in preparation with Drs Chappell and Taylor. The paper is to be a comprehensive account of the trace-element geochemistry of the New Britain and Witu Islands rocks.

WITU ISLANDS PETROLOGY

The Witu Islands overlie the deepest (300-600 km) part of the New Britain Benioff zone, and are at the southeastern end of the Willaumez-Manus Rise. Their petrology has been studied in detail - in collaboration with Dr R.J. Arculus (ANU) - because of the surprisingly wide variety of rock compositions found there, and because of the current interest in back-arc volcanism. Major- and trace-element analyses have been made on 29 rock samples, and isotope data (Sr and Nd), REE abundances, and microprobe-determined mineral compositions obtained for selected rocks.

The rocks of Unea Island are basalt and andesite which are similar in many respects to those of typical island-arc rocks. Basalt and andesite are also present on Garove Island, but together with dacite and rhyolite they form a suite which has some chemical characteristics more in common with the rocks of oceanic settings. Olivine tholeiite and quartz tholeiite make up Mundua, Undaka, and Wambu Islands; olivine tholeiite is typical of basalt found in inter-arc basins, such as in the Scotia Sea region, but quartz tholeiite is more like island-arc basalt. An analysed basalt from Narage Island has a distinctive geochemistry; it has the lowest silica content of all the analysed rocks from New Britain and the Witu Islands, and has a strongly fractionated REE pattern. Alkaline rocks appear to be absent from the Witu Islands.

These rocks appear to have originated from chemically diverse mantle sources. Water may have been derived from the deeper parts of the downgoing lithospheric slab beneath the islands, but if so its influence on petrogenesis appears to have been irregular, and it may not have significantly influenced all the source regions for the Witu Islands rocks. No unequivocal evidence has been found that slab melting has influenced the geochemistry of the source regions.

Sr-Nd ISOTOPE STUDY

Eight rocks from New Britain and Witu Islands volcanoes have been analysed for $^{87}Sr/^{86}Sr$ and $^{144}Nd/^{143}Nd$ values by Dr D.J. De Paolo of the California Institute of Technology, Pasadena. The rocks range from basalt to rhyolite, are from volcanoes overlying a wide depth range to the New Britain Benioff zone, and have widely different REE patterns. Despite this diversity, the ratios in each isotope set are similar, suggesting an isotopically uniform source. A light-REE-depleted source is inferred by the $^{144}Nd/^{143}Nd$ values which are similar to those for some oceanic-island volcanic rocks.

ISLAND-ARC REFERENCE SUITE

The National Aeronautics and Space Administration (NASA) has undertaken a Planetary Basaltic Volcanism Project which will include studies of representative terrestrial basalt suites from different tectonic settings. Dr Taylor (ANU) is undertaking the study of island-arc basalts, and has selected New Britain as a reference island arc. Rock chips and powders for twelve samples have been sent to NASA for their collection, and the first draft of a paper by Taylor, Johnson, Arculus, and Perfit on the petrology and geochemistry of island-arc rocks has been prepared.

VOLCANOES OF THE TABAR, LIHIR, TANGA, AND FENI ISLANDS by R.W. Johnson and D.A. Wallace

A study of the geology and petrology of these islands was initiated by the late G.A.M. Taylor, G.C., in the late 1960's, and continued by the Geological Survey of Papua New Guinea in 1973 and 1974. During the past year an attempt has been made to document the results of these surveys, and to add to the number of chemical analyses of rocks and minerals. Progress has been made on several fronts, including the completion of geological descriptions by Wallace, chemical analyses (X-ray fluorescence spectrometry) of about 60 additional rocks by Dr Chappell, $^{87}Sr/^{86}Sr$ determinations for about 20 rocks by Dr M.R. Perfit (Research School of Earth Sciences, ANU), and electron-microprobe determinations by Dr Arculus of mineral compositions for both lavas and cumulate inclusions.

The Tabar-to-Feni volcanoes have a wide range of mainly alkaline rock types, including alkali basalt, olivine nephelinite, tephrite, basanite, trachybasalt, trachyandesite, phonolitic tephrite, and trachyte. Silica-oversaturated rocks such as tholeiitic basalt, andesite, dacite, and rhyolite have not been found, although quartz trachyte is present on some islands. In most rocks K_2O/Na_2O values are greater than 0.5, and in a few they exceed 1. $FeO+Fe_2O_3$ values are less than 12 weight percent, and in most analysed samples Fe_2O_3/FeO values exceed 1. Like the alkaline rocks of oceanic islands, the Tabar-Feni rocks are characterised by high abundances of large-ion-lithophile elements, especially Sr, relative to those of hypersthene-normative rocks. Light REE are enriched relative to heavy REE in all the alkaline samples analysed. However, these alkaline rocks may be distinguished from those of oceanic islands by low TiO_2 contents (less than 1 percent), high Al_2O_3 contents (mainly greater than 16 percent), and high Zr/Nb values which are similar to those of hypersthene-normative rocks from island arcs and ocean floors. $^{87}Sr/^{86}Sr$ values range mainly between 0.7040 and 0.7044.

The rock mineralogy is also diverse. Clinopyroxene phenocrysts are generally more abundant than olivine, plagioclase, and Fe-Ti oxide phenocrysts in the more basic rocks, and clinopyroxene dominates the cumulate inclusions. In differentiated rocks, the phenocrysts include haüyne, analcite, leucite, amphibole, biotite, sodalite, and apatite.

The Quaternary volcanism of the Tabar-to-Feni Islands is not obviously related to present-day subduction, spreading axes, or mantle plumes. A preferred, but tentative, explanation is that the volcanoes overlie a fault zone above mantle modified by the introduction of large-ion-lithophile elements and water, possibly during the formation of the Tertiary New Ireland arc. However, the islands may overlie an old part of the Pacific plate, and if oceanic lithosphere thickens with age and distance form the spreading axis, and incorporates water-rich nephelinite-like melt from the oceanic low-velocity layer, then mantle modification beneath the Tabar-to-Feni change may have been an oceanic, rather than an island-arc, phenomenon.

GEOCHEMISTRY OF ANDESITES FROM BAGANA VOLCANO by R.J. Bultitude and R.W. Johnson

Chemically analysed rocks from Bagana, an active andesitic volcano on Bougainville Island, may be assigned to one of three age groups - pre-1943, 1943-53, or 1959-75. Rocks of the oldest group are the most fractionated, whereas those of the 1943-53 group are the most mafic. The rocks of the youngest group are intermediate in degree of fractionation, but have K_2O, Rb, and Ba abundances similar to, or lower than, the rocks of the 1943-53 group. The three groups appear to represent distinct batches of magma that were successively erupted from Bagana, possibly from a high-level reservoir that was periodically emptied and refilled. The andesites are regarded as fractionates of mantle-derived mafic magmas. Most of the crystal fractionation probably took place during ascent from the mantle source region, and before entry into the reservoir beneath the volcano. An average chemical composition of the analysed Bagana andesites has major-element values close to those of the mean for more than 800 analysed late Cainozoic volcanic rocks from Papua New Guinea, and is proposed as a reference andesite composition for comparative studies.

VOLCANOES OFF THE NORTH COAST OF MAINLAND PAPUA NEW GUINEA by R.W. Johnson

A suite of volcanic rock samples collected by C.O. McKee (Volcanological Observatory, Rabaul) from Manam and Karkar Islands has been chemically analysed by Dr Chappell for major and trace elements using X-ray fluorescence spectrometry. These new data bring the total number of analysed rocks from the north coast volcanoes to about 150, and there is now a uniform coverage of analysed rocks from this chain. The new data are consistent with the interpretation that there are systematic changes in chemistry along the volcanic chain - that is, in a direction parallel to the strike of the nearly-vertical lithospheric slab beneath the north coast of mainland Papua New Guinea.

PAPUA NEW GUINEA HIGHLAND VOLCANOES by D.E. Mackenzie

Mackenzie prepared a paper on the petrogenesis of the Papua New Guinea Highlands volcanoes, and presented it at the 2nd S.W.-Pacific Workshop Symposium in Sydney, December 1977; it is to be published in the Bulletin of the Australian Society of Exploration Geophysicists. In addition, he reviewed a manuscript by W. Hamilton (U.S.G.S.) dealing with the tectonics of Papua New Guinea.

PETROLOGICAL, GEOCHEMICAL, AND GEOCHRONOLOGICAL LABORATORIES

Supervising geologist: John Ferguson

STAFF: L.P. Black, B.I. Cruikshank, G.R. Ewers, John Ferguson, A.Y. Glikson, A.D. Haldane, A.L. Jaques (from June), D.H. McColl (part time), C.M. Mock (to August), R.W. Page, A.G. Rossiter, P.A. Scott, J.W. Sheraton, S.E. Smith, L.A.I. Wyborn (from January)

Technical Staff: G.W.R. Barnes, M.J. Bower, N.J. Davies (from November) J.L. Duggan (from September), K.H. Ellingsen, J.L. Fitzsimmons, R. Flossman (to May), N.C. Hyett, C.R. Madden (from January), J.G. Pyke, T.I. Slezak, T.K. Zapasnik.

PETROLOGY LABORATORY

ALKALINE ULTRAMAFIC ROCK PROJECT, by John Ferguson, L.P. Black, H.A. Jones, and J.C. Mutter (Geophysical Branch)

Recent discoveries have established the existence of fourteen areas where kimberlitic rocks occur in southeastern Australia in the States of New South Wales, Victoria, Tasmania, and South Australia. Isotopic dating has established Permian and Jurassic ages for certain kimberlitic occurrences in New South Wales and South Australia, respectively. Field relations indicate that all occurrences postdate the Proterozoic, and that some in N.S.W. are Tertiary or younger.

Owing to the fast emplacement of kimberlite and the attendant random sampling of upper mantle and crustal material it has been possible to attempt reconstruction models of geospheres down to upper mantle depths. Work is proceeding on xenolithic nodules from the upper mantle; these are dominated by ultramafic rocks, largely garnet and spinel lherzolites; mafic assemblages of eclogitic mineralogy are subordinate. The transition from garnet to spinel lherzolite facies is marked by the unique occurrence of an equilibrium lherzolite assemblage containing both garnet and spinel lying on the quasiunivariant boundary separating these lherzolite fields. P-T estimates for these garnet-spinel lherzolites are 1240^{o}C and 22 kb, indicating an abnormally high geothermal gradient, actually exceeding the oceanic geotherm. Garnet and clinopyroxene from one eclogite (griquaite) nodule are of identical composition to those from garnet lherzolite in the same area, suggesting derivation from a common mantle-source region. Other eclogitic inclusions are considerably more iron-rich, and probably represent lower-crustal material. Saturated and oversaturated felsic nodules have the granulitic assemblages plagioclase $\pm$ garnet $\pm$ quartz $\pm$ clinopyroxene $\pm$ orthopyroxene $\pm$ kyanite $\pm$ K-feldspars $\pm$ rutile.

Pressure-temperature (P-T) estimates for the upper-mantle and lower-crustal rocks indicate an abnormally high geothermal gradient throughout southeast Australia from at least Permian to Tertiary times.

As part of ongoing programs of marine geological research and potential mineral resource evaluation within the Bureau of Mineral Resources and the Department of Earth Sciences, Monash University (I.A. Nicholls), sampling of the manganese nodule field in the southeast Indian Ocean, south of Western Australia, has been carried out on several occasions. The most recent cruise was in July-August 1977, when manganese nodules were successfully dredged by the Royal Australian Navy frigate HMAS Diamantina in an area bounded by latitudes 38^{o}09' and 41^{o}00'S and longitudes 110^{o}04' and 118^{o}00'E. Weather conditions deteriorated badly late in this cruise, and forced curtailment of the manganese-nodule dredging program. Whilst running for shelter to Fremantle on 1 August 1977, a temporary improvement in sea state allowed an additional unprogrammed dredging station to be occupied north of the expected area of maximum manganese nodule development. It was at this station (36^{o}38'S, 112^{o}16'E) that the dredge recovered about 25 kg of angular and rounded rock fragments ranging from about 2 cm to 28 cm in diameter. All were heavily encrusted with iron and manganese oxides, and, except for their angularity and range of sizes, they superficially resembled the sedimentary manganiferous material collected from the manganese nodule field elsewhere in this region. Of these, three sampdes contain nodules of spinel lherzolite, two spinel pyroxenite, and one serpentinite. Using a number of methods of temperature and pressure estimation, the nodules give values in the region $1000^{\circ}C$ and 16 kb. These values are consistent with P-T estimates of the mean oceanic geotherm.

The samples were dredged in a tectonically complex area near the junction of the Diamantina and Naturaliste Fracture Zones. The occurrence of a volcanic rock with ultramafic inclusions in a part of the ocean floor interpreted as formerly the site of a continental rift system is not unexpected.

COPPER-BEARING BRECCIA PIPES, REDBANK, N.T., by Janice Knutson, John Ferguson, W.M.B. Roberts, T.H. Donnelly (CSIRO), and I.B. Lambert (CSIRO)

Copper-bearing breccia pipes in the Redbank area intersect a sequence of interbedded igneous and dolomitic sedimentary rocks which have undergone various degrees of metasomatism.

The steeply inclined breccia pipes are of small size and cylindrical form, and typically show in-situ brecciation. The breccia matrix and associated veins consist essentially of various proportions of microbreccia, dolomite, quartz, chlorite, celadonite, hematite, K-feldspar, apatite, chalcopyrite, and minor barite, rutile, galena, and pyrobitumen. K-metasomatism is most intense in the vicinity of the breccia pipes and associated veining, and there is mineralogical and textural evidence indicating that fluids enriched in K, Cl, P, Mg, Ce, La, CO_2, and H_2O were introduced at the time of breccia-pipe formation. Carbonate and sulphide minerals from brecciated and metasomatised rocks at lower stratigraphic levels have isotopic compositions consistent with magmatic hydrothermal derivation. However, the $\delta^{13}C$ values of the great bulk of the dolomite in the breccia pipes indicate remobilisation of sedimentary carbonate. Further, the sulphur-isotope ratios of the main sulphide mineralisation, which occurs near the top of the brecciated sequence, are variable, and the sulphides are generally enriched in ^{34}S relative to the minor amounts of sulphide at lower levels.

The breccia pipes formed by explosive release of fluids following the build-up of significant over-pressure in a postulated carbonated, K-rich, trachytic magma at depths of roughly 2 to 3 km beneath the surface. This was accompanied by intense metasomatism and precipitation of some carbonate and sulphide minerals which partly filled the open spaces. The thermal gradients and fracturing caused extensive circulation of connate brine (and possibly descending seawater). The brine remobilised sedimentary and magmatic hydrothermal components in and around the pipes, and copper mineralisation in the Redbank area precipitated mainly from this brine.

PETROLOGY AND GEOCHEMISTRY OF IGNEOUS AND METAMORPHIC ROCKS FROM ANTARCTICA, by J.W. Sheraton and D.J. Ellis (University of Tasmania; formerly with BMR)

Petrographic and geochemical investigations of igneous and metamorphic rocks from Enderby Land continued in conjunction with the 1:250 000-scale geological mapping of the area. About 180 samples, mostly collected during the 1977 field season, were analysed for major and trace elements.

Sapphirine-bearing metasediments (J.W. Sheraton, D.J. Ellis, R.N. England (Monash University), W.B. Dallwitz) Aluminous metasediments containing the high-temperature assemblage sapphirine + quartz have been found at eight localities over an area of about 2500 sq km in Enderby Land (pressure-temperature estimates by Ellis (see below) indicate that these rocks were metamorphosed at temperatures of at least 900^{o}C and pressures of 8-9 kb). To the south and west of this area, sapphirine + quartz gives way to the slightly lower-grade assemblage orthopyroxene + sillimanite. Osumilite with a composition near $K_{0.93}\ Na_{0.13}\ Mg_{2.04}\ Fe_{0.21}\ Al_{4.60}\ Si_{10.16}\ O_{30}$ is present in metapelites from several localities, and its characteristic breakdown product (a symplectite of cordierite, quartz, K-feldspar, and orthopyroxene) is even more widespread.

Although sapphirine + quartz has now been described from several other high-temperature granulite terrains, and osumilite is known in high-grade metamorphic rocks from at least two localities, the Enderby Land granulites are the only ones in which such assemblages are known to occur on a regional scale.

Garnet-forming reactions in crustal mafic rocks - an example from Amundsen Bay, Enderby Land (D.J. Ellis)

Studies of high-pressure mafic granulite demonstrate the effect of different bulk rock compositions on the variety of reactions involved in the development of garnet over the basalt-eclogite transition. The development of garnet in a quartz tholeiite dyke is consistent with previously described reactions such as the progressive reaction of plagioclase with orthopyroxene to produce garnet+ clinopyroxene+quartz ($\pm$ kyanite) with decreasing temperature, although kyanite is not present in the rocks under investigation.

In contrast, the disappearance of plagioclase in more mafic, quartz-free rocks involves a different series of reactions with decreasing temperature. Plagioclase initially reacted, during prograde metamorphism, to form aluminous clinopyroxene (+garnet+spinel), but at lower temperatures the marked decrease in solubility of aluminium in clinopyroxene resulted in unmixing and the formation of a second generation of plagioclase. This feldspar would eventually react at still lower temperatures, and form a more Ca-rich garnet and kyanite. However, the solubility of aluminium in clinopyroxene coexisting with plagioclase and quartz at the estimated pressures of metamorphism is largely independent of temperature; plagioclase is continually consumed with decreasing temperature.

The clinopyroxene (Cpx) in the mafic rocks has exsolved the following mineral assemblages -

$Cpx_1 \longrightarrow Cpx_2$ + Opx (orthopyroxene)
$Cpx_1 \longrightarrow Cpx_2$ + Opx + Garnet + Opaque Oxide
$Cpx_1 \longrightarrow Cpx_2$ + Garnet
$Cpx_1 \longrightarrow Cpx_2$ + Plagioclase + Qtz + Opaque Oxide

This wide range in mineral associations and compositions should permit the evaluation of the internal consistency of available methods of geothermometry and geobarometry for crustal granulites.

The mafic rocks were originally a series of cumulates crystallised from the enclosing basalt dyke at about 10 kb pressure. Subsequent regional metamorphism reached a peak at about 820^{o}C and 11 kb pressure, followed by cooling to about 720^{o}C at constant pressure, after which intercrystalline diffusion was too sluggish to record the further physical evolution of the granulites.

High-grade metapelites from Enderby Land (D.J. Ellis)

The Precambrian granulites of Enderby Land contain coexisting spinel-quartz, sapphirine-quartz, hypersthene-sillimanite-quartz, and osumilite on a regional scale. Osumilite is present in a variety of mineral assemblages, most of which have not previously been reported. Secondary cordierite has developed by a variety of mineral reactions. Regional variations exist in the distribution of the various mineral assemblages.

It is believed that the granulites reached a peak of metamorphism at 7.8-9.8 kb pressure, 900-950^{o}C, under conditions of P_{H_2O} less than PTotal. A series of complex mineral reactions seen in corona structures records the course of subsequent cooling history.

Temperatures deduced from various experimentally calibrated geothermometers vary widely, and in some cases are inconsistent with the stability fields of the actual mineral assemblages. For example, garnet-cordierite pairs indicate equilibration at 500-600^{o}C, well within the kyanite stability field, yet kyanite is absent. The possible effects of P_{H_2O}-P_{CO_2} and Al-Si ordering upon garnet-cordierite equilibria, and the validity of applying currently available experimental data to such high-grade metamorphic rocks are also being investigated.

A theoretical analysis of the phase relations involving osumilite in the chemical systems K_2O-MgO-Al_2O_3-SiO_2 and K_2O-FeO-MgO-Al_2O_3-SiO_2 will be made. Petrographic data, as well as chemographic relations, indicate that for many common rock compositions, garnet, cordierite, hypersthene, sapphirine, and sillimanite cannot coexist with both osumilite and K-feldspar.

Mafic Dykes (J.W. Sheraton) Chemical data on about 80 mafic to ultramafic dykes from Enderby Land, the Prince Charles Mountains, and the Vestfold Hills were subjected to statistical cluster analysis. The various cluster groups are generally similar to subdivisions made using petrographic criteria: metapyroxenites, dolerites, and alkali basalts. The dolerites form several subgroups - most are quartz tholeiites, but a few are olivine-normative. Clinopyroxene is the usual mafic phase, but a few dykes contain abundant phenocrysts of orthopyroxene; both types occur in the Vestfold Hills and in Enderby Land. Alkali basalts have been found only in the northern Prince Charles Mountains-Mawson Coast area, although a single dyke from the Bunger Hills is also of this type. No systematic chemical differences between fresh and metamorphosed dolerites were found. An ultrapotassic dyke from Enderby Land was found to be chemically similar to a magnophorite basalt from Mount Bayliss in the southern Prince Charles Mountains, although it is exceptionally rich in P_2O_5 (3%) and Ba (1-1.5%).

Felsic Gneisses (J.W. Sheraton) Felsic gneisses of two types are by far the most abundant rock types in Enderby Land. Massive orthopyroxene-quartz-feldspar gneiss, of roughly granitic composition, is generally diopside-normative or only slightly corundum-normative, consistent with a derivation from igneous rocks - acid volcanics, or possibly in the case of the most massive varieties, granitic intrusives. More strongly layered garnet-quartz-feldspar gneiss is almost invariably corundum-normative, and is considered to be of sedimentary origin. Such an interpretation is supported by its common association with a variety of aluminous, siliceous, and ferruginous meta-sediments.

Gaussberg (J.W. Sheraton, A. Cundari (University of Melbourne)) Further chemical analyses of the leucite basalt pillow lavas of Gaussberg in Whilhelm II Land have confirmed that the lavas belong to the rare suite of ultrapotassic subvolcanic and volcanic rocks. Very little chemical variation is apparent in samples collected from various parts of the volcano. There also appears to be very little chemical difference between pillow cores and glassy crusts. The cores merely have a much higher proportion of crystals (leucite, clinopyroxene, brown amphibole, and brown mica) in the groundmass, whereas in the crusts the groundmass is essentially all glass.

MOUNT ISA INLIER GRANITOIDS PROJECT by L.A.I. Wyborn

(L.A.I. Wyborn, C. Mock (to August), D. Wyborn (from August), in collaboration with mapping parties and Geochronological Laboratory)

Research into the geochemistry of granitoids of the Mount Isa Inlier was started in 1978 with two major aims: first, to elucidate the geochemistry of the various granitoid bodies, their intrusive history, and their economic potential, and second, to delineate, if possible, the nature of the deep crust of the Mount Isa Inlier, and to examine the evolution of the crust in space and time in this region. Complementary studies were to include granitoid geochronology, the relationship between metamorphism and granitoid intrusion, geochemical and structural relations between granitoid and felsic volcanic suites, and the relationship between granitoid and geophysical data.

Granitoids in the Mount Isa Inlier occur as large, composite plutons which consist of mainly medium to coarse rocks, and as small plutons (up to 5 km across) made up of fine-grained rocks. We propose to change the well-known names for major bodies in the region (e.g., Kalkadoon Granite, Karaku Granite, Wonga Granite) to batholith status.

Before the field season 96 samples of the Sybella batholith were submitted for analysis; 51 were from the Oban 1:100 000 Sheet area, and 45 from the Mount Isa 1:100 000 Sheet area, and they represented the three phases of the batholith present (Pgs_1, Pgs_2, and Pgs_3).

During the field season 120 samples were collected for analysis from representative parts of the Kalkadoon, Hardway, Naraku, Weberra, Wonga, Ewen, Wills Creek, and Wimberu Batholiths. They were collected from the Mount Oxide, Mount Isa, Mary Kathleen, Cloncurry, Marraba, Quamby, Alsace, Prospector, Duchess, Dajarra, and Malbon 1:100 000 Sheet areas. Sampling localities were severely restricted by ubiquitious alteration and foliation, and in the Duchess-Dajarra area work was further hampered by extensive, deep weathering. As geochronological work has been in progress for some years, one of the primary aims for the field season was to decide from which individual phases of the various batholiths the samples for age determination had been collected, and then to determine how the different phases are related to one another chemically.

Study of the material collected is in progress.

PILBARA GEOCHEMICAL PROJECT by A.Y. Glikson and A.H. Hickman (GSWA)

The analytical work on 465 samples of volcanic rocks from the eastern part of the Pilbara Block was completed toward the end of 1977. In late 1977 and early 1978 the data were entered on to magnetic tape, using the HP9825A desk-top calculator and storage-retrieval program written by M. Owen. Subsequently the data were calculated, plotted, and printed using the HP9871A printer and HP9872A plotter. The work included the study of the HP system and preparation of a number of computer programs suitable for geochemical studies. Topics investigated were:
(1) table printing; (2) computation and printing of CIPW norms, plagioclase compositions (normative), SI indices, differentiation indices, solidification indices, Mg number, etc.; (3) computation and printing of mean compositions, standard deviations, and correlation coefficients; (4) X-Y plots such as Ti-Zr, Ti-Mg', K-CO_2, Ni-Mg, etc.; (5) X-Y-Z plots such as F-M-A, Ca-Na-K, Ti-K-P, Cu-Pb-Zn, La-Ce-Y, Th-U-Nb, Sr-Rb-Ba, Ni-Cr-Co, etc.

The following computer programs were written:

1. Partial melting and fractional crystallisation mass-balance calculations for both major and minor elements, enabling the finding of source compositions or of percentage fractionation, where crystal/melt distribution coefficients are known and assumptions are made for the composition of fractionated phases. Five programs can be used, including (a) finding percentage melting, using a key major element (usually Mg) for a given rock (representing melt composition), and on the basis of petrologically logical predictions of the composition of source materials and fractionated mineral phases. (b) finding parental trace-element compositions for given rocks - percentage melting deduced from program (a). - and assumed fractionated mineral compositions. (c) finding percentage fractionation for a given trace-element composition, assumed source composition, and predicted distribution coefficients. Programs (b) and (c) can be used for either partial melting or fractional crystallisation. All programs recover data automatically from tape storage.

2. Frequency distribution plots, recovering data from tape according to selected search words, and including legend printing. Different colours can be used for individual graphs, and the diagrams are suitable for final production as slides or report figures.
3. Stratigraphic level-controlled geochemical variation plots, recovering the columnar stratigraphic position from tape.
4. Molecular proportion logarithmic plots based on the Beswick and Soucie (1978) method for an assessment of degrees of alteration. The method is based on assumed low mobilities of Al and Si during low-grade metamorphism, and the program allows an estimate of secondary diffusion to be made. Precise alteration computations will be carried out by A.E. Beswick (Laurentian University, Ontario).
5. Normative rock-name classifications for acid igneous and for ultramafic compositions, based on the An-Ab-Or and Ol-Opx-Cpx ternary diagrams.
6. Computations of maximum crustal residence time of precursors of igneous rocks from their Rb-Sr isotopic data, given isochron age and initial Sr^{87}/Sr^{86} values, assuming plausible Rb/Sr ratios of the precursors, and a linear Sr^{87}/Sr^{86} mantle growth curve.

By early October the Pilbara data had been processed by programs (2) and (3) and processing by programs (1) and (4) was then started. The data were also entered on IBM cards used for cluster analysis (Bonham-Carter program) on the Cyber computer. The cards will also be used for the CMAS tetrahedron plots of O'Hara and for R-mode factor analysis. It is envisaged that the statistical processing should be completed by the end of 1978. The Pilbara data will be compared with data for Archaean and Palaeozoic volcanic rocks stored on magnetic tape (about 700 analyses recorded at present), and with data for modern oceanic and island-arc volcanics (to be recorded on tape), and with averages and distribution fields taken from the literature. It is planned to start writing a Record about January, 1979. Many of the tables and plots accompanying the report will be presented in microfiche.

A rare-earth-element study of selected sampdes has been undertaken in collaboration with Dr Borming Jahn (University of Rennes, France). To date 28 samples of acid volcanic and plutonic rocks have been analysed, yielding diagnostic and distinct signatures for the various formations. Some Rb-Sr isotopic work on the same samples has also been undertaken. The work is continuing, and should form the basis for one or more joint papers by Jahn and BMR and GSWA workers. An isotopic study of Sm and Nd has been undertaken by Dr J. Hamilton, Lamont Doherty Geological Observatory, Columbia University, New York.

Most of the samples were also subjected to X-ray diffraction analysis because of their fine grain-size. The mineralogical data will be entered onto magnetic tape, and used for classifying the geochemical data and determining chemical redistribution patterns brought about by metamorphism. Distribution patterns of trace metals of economic significance - i.e., Cu, Zn, and Pb - in relation to other geochemical and mineralogical indices, are being examined.

ARCHAEAN STUDIES by A.Y. Glikson

On the invitation of Dr F. Barker (U.S. Geological Survey) a paper has been written on 'Early Precambrian tonalite-trondhjemite nuclei', and has been submitted to Earth Science Reviews. The paper 'Precambrian sial-sima relations: evidence for Earth expansion?' has been accepted for Tectonophysics. A joint contribution by J.A. Hallberg and A.Y. Glikson entitled 'Archaean granite-greenstone terrains of Western Australia' has been completed for the volume 'Precambrian of the southern hemisphere' edited by D.R. Hunter. A paper was submitted to the volume on 'Archaean Geochemistry' (eds B.F. Windley and S.M. Naqvi), entitled 'Archaean granite series and the early crust, Kalgoorlie System, Western Australia'. A paper was written under the title 'The missing Precambrian crust', in which the radius of the Precambrian Earth was discussed. The paper 'On the basement of Canadian greenstone belts' appeared in Canadian Geoscience, with an accompanying discussion by W.R.A. Baragar and J.C. McGlynn, of the Geological Survey of Canada. Seminars were given at the Australian National University Research School of Earth Sciences and the Department of Geology. A paper entitled 'The Pilbara Craton: elements of an Archaean granite-greenstone system', was read by R.T. Pidgeon for the author at the conference on Archaean Geochemistry at Thunder Bay, Ontario, in August.

STRANGWAYS CRYPTOEXPLOSION STRUCTURE, N.T., by John Ferguson

This project is being jointly undertaken with:

R. Brett (National Science Foundation, U.S.A.);
M.R. Dence (Energy, Mines & Resources, Canada);
D.J. Milton (U.S. Geological Survey);
C.H. Simonds (Northrop Services Inc., U.S.A.); and
S.R. Taylor (Australian National University)

The Strangways cryptoexplosion structure, about 80 km southeast of Mataranka, is a circular feature containing abundant evidence of shock metamorphism. The core consists of granite gneiss, of about 5 km radius, surrounded by a collar of Proterozoic quartzite and siltstone. No definitely coherent bedrock is exposed in the core; exposures are breccia, commonly highly shocked, or melt rock rich in clasts - all gneiss, or gneiss and sediments in different areas. Two cored holes have been drilled into the melt rock to obtain fresh samples and to obtain samples of bedrock, if possible.

In the collar, about 5 km wide, quartzite forms ridges of steeply dipping, outward-facing strata, which commonly extend outward into overturned flaps, presumably lying on poorly exposed siltstone. In one sector the outermost quartzite forms a flap of nearly horizontal overturned beds 4 km wide, making the diameter of the disturbance about 22 km. The innermost quartzite is largely breccia both in the strike ridges and flaps; breccia is minor in the other quartzite ridges. Shatter fracturing - more commonly intersecting sets of striated cleavage surfaces than well-formed cones - is well developed in the inner quartzite of the collar, but is rare toward the outside. Anomalous features are small patches and house-sized blocks of at most weakly shocked quartzite resting on gneiss up to 1.5 km inside the normal contact between core and collar rock, and rare blocks of shocked gneiss as far as 0.5 km outside. In the northwest corner of the structure there is a flat-lying carbonate unit, which appears to post-date the explosive event, and is possibly Cambrian Tindall Limestone; a cored hole has been drilled into this unit.

The basic structure suggests Vredefort, but the melt rock and the flaps indicate a shallower level of exposure. The occurrence of the flaps at about the same elevation as the base of the melt layer is surprising. Are they features of the collar rocks outside the central uplift or of the floor inside?

PINE CREEK GEOSYNCLINE, N.T., by John Ferguson, G.R. Ewers, T.H. Donnally (CSIRO), and A.G. Rossiter.

Cooperating workers: Members of Pine Creek geological party and geophysicists; P. Winer (A.N.U.)

A comprehensive petrological, geochemical, geophysical, and mineralogical study of a wide spectrum of rocks, and of uranium mineralisation, in the Pine Creek Geosyncline is at the writing-up stage.

Two mafic rock units were investigated in some detail: the Oenpelli Dolerite (P.G. Stuart-Smith and Ferguson) and the Zamu Dolerite (Ferguson and R.S. Needham).

The Oenpelli Dolerite comprises at least four major sheet-like intrusions up to 250 m thick of continental tholeiitic composition which have a lateral extent of about 20 000 km^2. The intrusions were emplaced about 1720 m.y. ago into Lower Proterozoic metasedimentary rocks of the Pine Creek Geosyncline, postdating an 1800 m.y. regional metamorphic event. The intrusions consist of symmetrically differentiated layers of olivine dolerite, minor felsic differentiates, and rare crosscutting gabbroic pegmatite. Within the thicker sheets minor rhythmic layering is found in olivine dolerite.

The Oenpelli Dolerite contains normative orthopyroxene, and its major- and trace-element chemistry closely parallels the trends of major continental mafic tholeiitic suites.

Projection of the chemical data into the anhydrous CMAS system shows that the rocks crystallised in the pressure range 1 atmosphere (atm.) to 5 kilobar (kb). The close match between the observed quilibrium and the 1 atm. phase diagrams for dry tholeiitic magmas suggests that the last equilibration of these magmas was at very low pressure. It is concluded that the tholeiitic Oenpelli Dolerite rocks have evolved by polybaric olivine fractionation during slow, or intermittent, uprise from higher-magnesia magma generated by partial melting within the upper mantle; plagioclase is an additional liquidus phase at shallow-crustal levels.

The term 'Zamu Dolerite' is proposed here to replace 'Zamu Complex' - the name originally applied to the predominantly mafic intrusives of the South Alligator River area - and also to include the other mafic supracrustal intrusive rocks which, with minor felsic differentiates, were emplaced into the strata of the Pine Creek Geosyncline before an 1800 m.y. phase of regional metamorphism. This suite of Lower Proterozoic rocks generally forms conformable intrusive tabular bodies which are folded and, in most places, metamorphosed with the enclosing strata. The intrusions are mostly amphibolite, but in the type area of Zamu Creek, folded but unaltered dolerite is found. The Zamu Dolerite occurs in two broad zones of regional metamorphic grade - medium and/or high grades in the north-easterly part of the region, and low grades elsewhere. Late-orogenic Carpentarian granite diapirs have, however, locally superimposed a contact metamorphism on the trace of the low-grade regional metamorphic event. Low-temperature retrograde metamorphism is locally present throughout the Pine Creek Geosyncline, being particularly prevalent within areas of uranium mineralisation.

Compared to dolerite, amphibolite has the following chemical characteristics: total Fe and Ti enrichment; Mg, K, and Sr depletion; similar values for Zr, Y, Nb, and P_2O_5; lower K:Rb and higher K:Ba ratios. The dolerite and amphibolite are orthopyroxene normative, and their major- and trace-element chemistry demonstrates that they closely parallel the trends of continental tholeiitic suites. The compositions of the mafic suite of the

Zamu Dolerite recast into the 1 atm. phase diagrams for simplified anhydrous tholeiitic magmas suggest that the more evolved members of this suite were produced by olivine, and possibly plagioclase, fractionation.

In order to assess the controls of uranium mineralisation in the Pine Creek Geosyncline work continued on a broad petrochemical basis; additionally, detailed studies of mineral paragenesis were undertaken with particular emphasis on the opaque and transparent minerals in the uranium-enriched zones and on stable isotope studies.

The 'early' granitoid rocks of the Pine Creek Geosyncline are Archaean, and the 'later' ones Lower to Middle Proterozoic. In all cases these rocks are anomalously enriched in uranium by a factor of 2 to 4 compared to the world-average abundance for these rock types. Almost without exception the granitoids in the geosyncline demonstrate a chemistry (high Na_2O/K_2O, and $Al/(Na + K + Ca/2) = 1.1$) and mineralogy (sphene, allanite, hornblende, biotite) that indicate that they have been derived from an igneous source (I-type granites). The Archaean granites formed the provenance area to the uranium-enriched Lower Proterozoic sediments.

Documentation was carried out of the compositions of Middle and Lower Proterozoic supracrustal igneous rocks and granites in the areas of Halls Creek, Pine Creek, Tennant Creek, Mount Isa, Georgetown, and Broken Hill. This project is being undertaken in order to interpret the Proterozoic mega-tectonic model for northern Australia and its economic implications.

Statistical element correlations were carried out on the rock units that are hosts to the uranium deposits with the following results for uranium at 99% confidence limit:

Cahill Formation	U correlates with W, As, Nb, Mo, Pb, Li, Sc
Golden Dyke Formation	U correlates with Li
Koolpin Formation	U correlates with Ti, P, Y, Ni, Cu, Zn, W, Nb, Pb, Li

In the case of the Cahill Formation a correlation 'filter' was used to test the 99% confidence limit for a condition where U was in excess of 40 ppm in the rock, giving the following:

U correlates with As, Nb, Mo, Pb, Sc

A feature common to all the major uranium deposits in the Alligator Rivers uranium field is the ubiquity of chlorite both within the outside the mineralised zones. The chlorite varies in form, grainsize, and origin, and commonly more than one generation is present. It has been recognised that where mineralisation occurs, it is invariably and intimately associated with chlorite. The significance of this association and its relevance to ore genesis has been investigated by examining the varieties of chlorite within and outside the mineralised zones. Detailed analysis of chlorite from mineralised and unmineralised material has shown that the oxidation state of the iron does not vary systematically. This suggests that redox reactions, which involve iron and may lead to uranium deposition, are relatively unimportant. A paper outlining the results of this study is being prepared for presentation at the International Uranium Symposium on the Pine Creek Geosyncline (see below).

Carbonates and sulphides are frequently intimately associated with uranium-enriched breccia zones. In order to test the conditions of deposition of these minerals stable isotope studies were undertaken. Most of the sulphides have isotopic values which suggest formation from H_2S produced by bacterial sulphate reduction. Vein and vug carbonate appears to have been derived from marine carbonate which, to varying degrees, has incorporated organically derived CO_2. Temperatures of deposition, as indicated by a combined study of stable isotopes, fluid inclusions, and illite/chlorite transitions, suggest that the uranium ore-forming solutions were low-temperature, probably below 150^{o}C.

As part of a wider magnetics and stable isotope study (involving D.H. Tucker, Ewers, and T.H. Donnelly), the opaque mineralogy of a suite of rocks from selected drillholes across the Pine Creek Geosyncline has been described. The samples are mainly amphibolite and carbonaceous shale, and come from rock units giving a strong magnetic response. It has been found that in the Litchfield and Alligator Rivers areas, the magnetic response is largely due to the presence of magnetite, whereas in the central area of the geosyncline it is due exclusively to pyrrhotite. On the eastern side of the geosyncline the transformation from pyrrhotite to magnetite appears to correlate with an abrupt change in metamorphic grade observed by Ferguson and R.S. Needham.

Progress is continuing on the organisation of 'The International Uranium Symposium on the Pine Creek Geosyncline' to be held in Sydney 4th-8th June 1979. A committee was formed to promote geological and geophysical investigation of uranium mineralisation within the Geosyncline; the members are G.H. Taylor, CSIRO; J.C. Rowntree, Pancontinental Mining Limited; and John Ferguson.

X-RAY DIFFRACTION, by G.W.R. Barnes

Fifteen hundred samples were analysed by X-ray diffraction. About one tenth of the work completed was ad hoc determinations. The remainder (14 group or individual projects) are tabulated below:

1. A.Y. Glikson: 26% - Total-rock mineralogy of ultramafic, mafic, intermediate, and acid rocks from the Pilbara region, W.A.
2. T.H. Donnelly and I.B. Lambert: 17% - Mineral identification for isotope work on sulphides and carbonates from Mount Gunson, Kapunda, and Marion Lake in S.A., and from McLeod Basin, Big Stubby, North Pole, and Yandicoogina in W.A.
3. R.V. Burne and James Ferguson: 10% - Clays, carbonates, and sulphates from Spencer Gulf, S.A.
4. T.H. Donnelly and John Ferguson: 6% - Mineralogy of sulphides for sulphur isotope determinations.
5. John Ferguson: 6% - Clay determinations and search runs for coesite/stishovite from material from the Strangways structure, Northern Territory.
6. P.J. Davies and J.F. Marshall: 5% - Carbonates from the Great Barrier Reef, Queensland.
7. J.B. Colwell: 4% - Clays, carbonates, and heavy mineral suites from late Cainozoic sediments, southeast S.A.
8. I.B. Lambert: 4% - Sediments from the Stuart Shelf, S.A.
9. C.M. Mock: 3% - Feldspar determinations on granites from Queensland.
10. D.H. McColl: 2% - Identification of museum specimens.

11. B. Bubela and C.R. Robison: 2% - Identification of synthetic carbonate phases from Baas Becking tank experiments.

12. J.W. Sheraton and L.A. Offe: 2% - Identification of unusual minerals from Antarctic rocks.

13. M.R. Walter: 2% - Mineralogy of carbonates and sulphates.

14. G.R. Ewers: 1.5% - Clays from Jabiluka, Koongarra, and Ranger uranium deposits.

At times the facilities of the laboratory are used to help other Government departments and the police in their investigations.

CHEMISTRY LABORATORY

ARALUEN GEOCHEMICAL PROJECT by S.E. Smith and P.A. Scott

The geochemical survey of the ARALUEN 1:100 000 Sheet area commenced in the latter half of 1977. The object was to obtain an understanding of geochemical dispersion patterns in temperate terrains with possible spin-offs for regional geological mapping and assessment of the economic potential of the areas.

Geomorphologically the map area can be divided into two parts

A. Tableland area consisting of gentle to moderately steep undulating country with strong soil development.

B. Coastal escarpment area, which is deeply-incised, very steep country with very little soil development.

In order to study dispersion patterns throughout the map sheet, different sampling techniques and different sampling media were tested in the two areas.

It was decided that the materials to be sampled in areas of low to medium relief would be residual soils and stream sediments. In areas of high relief only stream sediments would be collected. The main rock types in the area covered by soil sampling are granites and Silurian volcanics. A sampling grid of 1000 x 2000 metres was chosen for the granitic bodies and 500 x 500 metres for the more complex Silurian volcanics. Areas of particular interest were to be sampled in more detail. The sampling programme was to be carried out over two field seasons, 1977/78 and 1978/79. The samples are to be analysed for As, Ba, Bi, Ce, Co, Cr, Cu, Fe, Mn, Mo, Nb, Ni, Pb, Rb, Se, Sn, Sr, Th, Ti, U, W, Y, Zn, and Zr.

In the 1977/78 field season 1100 samples were collected covering most of the Bendoura, Kain, Krawaree, Snowball, and parts of the Monga, Araluen, and Burrumbela 1:25 000 Sheet areas. The analyses should be completed in November.

Three areas containing anomalous lead-zinc values have been detected in the Silurian volcanics. One of these is associated with the Krawaree lead-zinc deposit, but, as far as is known, no mineralisation has been recognised at the other two localities. Two soil samples from granitic areas have high lead-zinc values, but it has not been possible to define the size of the anomalous areas because of the low sampling density used over the granites. An area of anomalous arsenic values was identified in granite near Majors Creek. Further sampling will be carried out in these areas during the 1978/79 field season.

REGIONAL STREAM - SEDIMENT SURVEYS, by A.G. Rossiter and P.A. Scott

The BMR's regional geochemical surveys are designed to delineate those parts of Australia where more detailed mineral exploration should be concentrated, and to establish the geochemical techniques most likely to succeed in those regions.

Progress on the six 1:100 000 Sheet areas sampled to date is indicated in Figure M21. Field work in the Mammoth Mines area (northwest Queensland) was completed in 1978, and computer processing of the results for the Seigal, Hedleys Creek (N.T.-Queensland border area) Gilberton, and Georgetown (north Queensland) surveys continued. Computer methods for producing legends for geochemical maps were developed, and drafting of the maps has been almost fully automated.

1:100 000 SHEET NAME	COLLECTION OF SAMPLES	CODING OF FIELD DATA	CHEMICAL ANALYSIS OF SAMPLES		CODING OF ANALYTICAL DATA	PUNCHING OF COMPUTER CARDS	DATA IN STORAGE/ RETRIEVAL SYSTEM	DIGITISING		CARTOGRAPHY		PRINTING OF MAPS	PREPARATION OF REPORT
			AAS	XRF				SAMPLE POSITION	GEOCHEMICAL SYMBOL POSITION	AUTOMATED	MANUAL		
FORSAYTH (QLD)													
SEIGAL (NT)													
HEDLEYS CREEK (QLD)													
GILBERTON (QLD)													
GEORGETOWN (QLD)													
MAMMOTH MINES (QLD)													

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Fig. M21 Current status of BMR's regional stream-sediment surveys

The Forsayth (north Queensland) 1:100 000 geochemical maps were released during the year, and a number of areas worthy of more detailed exploration for tin and uranium were brought to notice.

CASE HISTORIES OF B.M.R. GEOCHEMICAL EXPLORATION, by A.D. Haldane

Following the publication by the Association of Exploration Geochemists of a volume of case histories and derived conceptual models based on Canadian geochemical exploration, the Bureau was approached by CSIRO for material to be included in a similar Australian volume. Seven case histories have been prepared to date on geochemical work in the Georgetown, Westmoreland, Tennant Creek, McArthur River, Torrington, and Mount Garnet areas. Two more - Captains Flat and Rum Jungle - are planned. The case histories cover examples of secondary dispersion in soils and stream sediments of a number of elements, including copper, lead, zinc, uranium, tin, molybdenum, beryllium, arsenic, bismuth, thorium, cobalt, nickel, and tungsten.

THE ASSOCIATION OF URANIUM WITH SKARN DEVELOPMENT IN THE MARY KATHLEEN AREA, QUEENSLAND, by B.I. Cruikshank, John Ferguson, and G.M. Derrick.

The Mary Kathleen orebody and the nearby Rita prospect occur in units of garnet-rich skarn which, although now chemically and mineralogically identical, have been formed from markedly different parent rocks. The skarn containing the Rita prospect is metasomatised marble, and shows statistically significant additions of Ti, Al, Fe, Mn, and H^+, and loss of Mg, Ca, K, and CO_2. The orebody skarn is metasomatised conglomerate, and analysis of matrix material (Derrick, BMRJ, 2, 123-130, 1977) implies addition of Fe, Mg, and Ca and loss of Si and K.

The source of these metasomatising fluids appears to be the residual magma of the Burstall Granite, released into the country rock during the emplacement of a swarm of uranium-rich rhyolite dykes. Transfer of material from units rich in certain elements (e.g., Ca, Mg, etc.) to those deficient in them seems feasible, as does the introduction of certain minor and trace elements (e.g., Ti, U, rare earths) in fluids from the residual magma. The quantity of Fe introduced during metasomatism of both marble and conglomerate units seems to indicate remobilisation from within other units of the sedimentary pile, as the Burstall Granite itself is deficient in iron relative to the world-average granite. A tentative mechanism for the transport of Ca, Mg, Fe, U, and rare earths, based on $CO_2/HCO_3^-/CO_3^=$ equilibria, is being considered.

ANALYTICAL LABORATORY, by B.I. Cruikshank.

STAFF: B.I. Cruikshank, K.H. Ellingsen, G.R. Ewers, J.L. Fitzsimmons, C.R. Madden, J.G. Pyke, J.W. Sheraton, T.I. Slezak.

This year the laboratory handled 4,560 samples for a total of about 80 000 element determinations. Most of the samples came from four projects:

1. Georgetown geochemical survey - 2620 samples,
2. Araluen geochemical survey - 1190 samples,
3. Antarctic geochemistry - 200 samples,

and 4. Duchess geochemistry - 120 samples.

Highlights for the year include the installation of on-line data processing for the older of the laboratory's two X-ray fluorescence spectrometers; the development of apparatus for the determination of CO_2 and H_2O+ in rock samples; and the purchase of a plate comparator for use with the emission spectrograph.

A program for disposing of obsolete equipment has been initiated.

X-RAY FLUORESCENCE SPECTROMETRY

Six hundred and fifty silicate samples (6500 element determinations), mostly from the Antarctic, Duchess, and Adelaide Geosyncline projects, were analysed on the major-element program.

Trace elements were determined on 4350 samples (51 400 element determinations), mostly from the projects listed above.

ATOMIC ABSORPTION SPECTROPHOTOMETRY

Three thousand samples (17 800 element determinations), mostly from the projects listed above, were analysed.

MISCELLANEOUS DETERMINATIONS

About 200 Georgetown heavy mineral samples were analysed by qualitative emission spectrography, each for 17 elements.

Three hundred and seventy samples, mostly from the Antarctic and Duchess projects, were analysed for FeO. Twelve Lake George and seventy Molonglo River water samples were also analysed.

GEOCHRONOLOGY LABORATORY

by

R.W. Page and L.P. Black

STAFF: L.P. Black, M.J. Bower, N.C. Hyett, R.W. Page, and T.K. Zapasnik

GENERAL

During the past year the Geochronology Group continued to use the joint Rb-Sr and U-Pb isotope laboratory facilities in the Research School of Earth Sciences, ANU, and we aknowledge the continuing cooperation and assistance of the Director and staff of the School.

The rock crushing-mineral separation laboratory functioned well during its first full year of operation since being reconstructed. During the year, 30 mica separates and 53 total-rock powders were prepared. Most time and effort went into zircon separations, nine of which were completed; these included two long and difficult separations on a 100-kg sample of a 5 cm-thick tuff marker bed from the Mount Isa orebody (see below), and on a 300 -kg sample of a tholeiitic basalt from the Eastern Creek Volcanics (also Mount Isa area).

Geochronological work in the past year has been equally divided between the Rb-Sr and U-Pb zircon methods. The chemical preparations for both techniques are done using different facilities in the same laboratory. Continous minor improvements have been made to this laboratory during the year, and our overall Rb, Sr, U, and Pb processing blanks have improved to gratifyingly low levels. Several weeks were spent in preparing and re-calibrating new ion-exchange columns for Rb-Sr work. New calibration has led to an effective lowering of the Sr blank from 6 to 3.5 ng and Rb from 6 to 1.5 ng per analysis.

During July and August, Page spent five weeks at the Royal Ontario Museum in Toronto, Canada. During this time he used a new multi-sample capsule (developed by Dr T.E. Krogh of R.O.M.) for the hydrothermal dissolution of zircon. Use of this method, together with a newly available pure Pb-205 isotopic tracer, offers a considerable advantage over existing techniques in terms of time saved and improved total-Pb processing blanks. On the way back to Canberra, Page (on leave) attended the Fourth International Conference on Geochronology in Colorado, and delivered a paper on aspects of U-Pb zircon and Rb-Sr total-rock geochrnology in the Mount Isa area.

Black gave two talks at ANU and one at BMR on the significance of Rb-Sr total-rock ages in polymetamorphic and multiply deformed environments. This was also the topic for a talk delivered at the Fourth International Conference on Geochronology, Cosmochronology, and Isotope Geology in Colorado during August. Whilst overseas, Black inspected some of the leading geochronology laboratories in the U.S.A., and then, whilst on recreation leave, visited prominent European laboratories. He was most concerned with learning the latest technical developments and applications of Rb-Sr, U-Pb zircon, and Sm-Nd dating. The Sm-Nd method has an advantage over the other two methods in that its application is not significantly affected by metamorphism, sedimentary processes, alteration, and weathering. It is ideal for dating old and altered igneous rocks, such as those in greenstone belts. In conjunction with Rb-Sr work it can be used in assessing continental-crust contamination in igneous rocks. Knowledge gained on the trip will be used to change our Rb-Sr chemical procedures in several small, but important, ways. The feasibility of beginning the relatively new Sm-Nd dating method in the joint ANU-BMR laboratory will be investigated.

MOUNT ISA PROJECT, by R.W. Page

The aim of this project is to establish a detailed chronological framework for several of the Precambrian volcanic and intrusive sequences by U-Pb (zircon) and Rb-Sr dating. This work has gradually allowed us to better clarify the Precambrian geological history of the region, and so improve overall stratigraphic correlations.

Additional samples of some of the oldest metavolcanic sequences were analysed. These include a migmatitic variant of the Leichhardt Metamorphics, and a meta-dacitic rock from the Rifle Creek Beds. Zircon from the former unit give a U-Pb age of between 1820 and 1840 m.y., indicating that this unit is probably a younger variant of the Leichhardt Metamorphics.

Gneissic to slightly foliated granitic bodies which intrude upper units in the Mount Isa succession are exemplified by the Wonga and Burstall Granites. Earlier U-Pb zircon work on the Wonga Granite gave an age of 1670 ± 8 m.y., but new zircon analyses on a sample from 13 km north of the previous sampling site indicate a U-Pb crystallisation age of about 1740 m.y. A slightly younger U-Pb age of 1720 m.y. has been obtained for zircon from the Burstall Granite; as is usually the case for Mount Isa-type environments, this is some 10% older than the Rb-Sr total-rock age. The zircon data appear to indicate that these are crystallisation ages for the granites, but further samples are being analysed to test the interpretation.

Considerable effort was devoted to determining the zircon age of a 5 cm-thick tuff bed, which is one of scores of such volcanic layers interbedded with stratiform ore-bodies in the Urquhart Shale of the Mount Isa Group. The 100 kg tuff sample yielded 8 mg of zircon which was hand-picked into ten fractions for U-Pb analysis. The analysed fractions mostly consisted of equant euhedral grains between 30 and 80 microns across.

The zircon U-Pb results point to an upper Concordia intercept between 1650 and 1670 m.y., and this is interpreted as the age of zircon crystallisation, and hence would be a good estimate for the age of the tuff bed itself. This result is the best available estimate for the age of the Mount Isa Group, and it is geologically consistent with the 1680 m.y. zircon age for the older Carters Bore Rhyolite, a volcanic unit immediately below the Mount Isa Group. All the Mount Isa area sedimentary and volcanic successions from the Leichhardt Metamorphics (1870 m.y.) to the Mount Isa Group (1670-1650 m.y.) were thus deposited within about 220 m.y.

ALKALINE ULTRAMAFIC PROJECT, by L.P. Black

There was little progress on this project over the past year for available kimberlitic rocks from Western Australia were found to be unsuitable for Rb-Sr dating. Ten isotopic analyses were made for Rb and Sr.

ARUNTA BLOCK, by L.P. Black

Work on samples collected between 1972 and 1975 should be completed by the end of 1978, when there will be a general assessment of all geochronological data. Fifty-six samples were isotopically analysed during the year. An article on the ultrapotassic rocks of the Mordor Complex was published in Contributions to Mineralogy and Petrology.

A co-operative study on the Mud Tank Carbonatite with B.L. Gulson of MRL, CSIRO, has been completed and published in the BMR Journal. It provided similar U-Pb zircon and Rb-Sr total-rock ages of about 732 m.y., which define the crystallisation time, and probably also the emplacement age, of the carbonatite. Rb-Sr mica ages of about 320 m.y. suggest that deformation structures in the carbonatite were caused by fault movement during the Alice Springs Orogeny. The presence of feldspar in the carbonatite appears to indicate country-rock contamination. The carbonatite differs markedly, both in age and initial $^{87}Sr/^{86}Sr$ ratio, from the ultrapotassic Mordor Igneous Complex (1210 m.y.) 50 km to the south. The age of the Mud Tank Carbonatite does not correspond with that of any other known event in the Arunta Block.

WESTERN TASMANIA, by L.P. Black

Following work several years ago, which showed that Rb-Sr total-rock systems in the Mount Read Volcanics preserve deformational rather than stratigraphic ages, it was decided to re-date these rocks using the U-Pb zircon technique. Zircon has been extracted from rocks from two localities, and awaits final purification before analysis.

HERBERTON-MOUNT GARNET AREA, by L.P. Black

Sixty four rocks and minerals were isotopically analysed for Rb and Sr. The data on the age of mineralisation and its temporal relation to the spatially associated granitic rocks, which was summarised in last year's Annual Report, have been published in the BMR Journal. Rb-Sr analyses of the Almaden Granite, although not yet fully assessed, reveal that it was emplaced essentially in a single episode about 300 m.y. ago, unlike some other granitic variants in the area (e.g., the Elizabeth Creek Granite) which show an age range of more than 20 m.y.

ENDERBY LAND, ANTARCTICA, by L.P. Black

Black spent three months with L.A. Offe collecting samples from 26 sites for isotopic dating. This sampling was in close liaison with P.R. James, of the University of Adelaide, who provided structural backing so that the deformation-dating technique, which has been so successfully used in north Queensland, could also be attempted in this area. Samples from the first of the sites, a paragneiss at Mount Hardy, have now been prepared. A number of powders await preliminary X-ray fluorescence determination for Rb and Sr, and a zircon concentrate is ready for hand-picking.

GEORGETOWN INLIER, by L.P. Black

Although forty six samples were analysed during the year, thus completing two sub-projects, final assessment of the data has yet to be made. However, the data show that, even though composite, the Newcastle Range Volcanics formed during a short event about 310 m.y. ago. Rb-Sr work on the Barnard Metamorphics, east of the inlier, suggests that these rocks were not deposited in the Precambrian, but in the Palaeozoic, and underwent their complex deformation and metamorphic history during the late Palaeozoic, as suggested by de Keyser (J. geol. Soc. Aust., 12, 91-103, 1965).

INTERNATIONAL ACTIVITIES

VISIT TO PEOPLE'S REPUBLIC OF CHINA, by K.A. Plumb

Plumb was a member of a group of seven geoscientists who visited China from 5-24 June, 1978, under a joint agreement between the Australian Academy of Science and Academia Sinica. His particular interests were in Precambrian geology, correlation of Precambrian sequences, and tectonics and tectonic mapping; other aspects of the group's interests are reported elsewhere in the Summary of Activities.

Visits were made to Institutes of Geological Research of Academia Sinica and the Bureau of Geology in Peking, to the Palaeontological Institute, Academia Sinica, in Nanking, and to the University of Nanking, Nanking. Field visits were made to Precambrian sequences at Chihsien, Tientsin Province, and to Kunming, Yunnan Province.

There are close parallels between the tectonic development of China and Australia; Chinese tectonists follow principles similar to those used in compiling the Tectonic Map of Australia and New Guinea, 1971, and their work appears to be of high quality. Essentially, China is divided into: (1) the ancient Sino-Korean Platform of northeastern China, which has an Archaean to early Proterozoic basement overlain by Proterozoic and Phanerozoic covers, and may be compared with the North Australian Craton; (2) the Yangtze and Tarim Platforms of southwestern and northwestern China, which have basements of early to late Proterozoic age overlain by late Proterozoic and Phanerozoic covers, and which may be compared with the Central Australian Platform Cover and its basements; (3) the South China Geosynclinal System, of Caledonian and Varisc an age, which may be compared with the Tasman Fold Belt (Geosyncline); (4) other Palaeozoic geosynclinal belts within the present continental block - the Central Asiatic-Mongolian Arcuate Fold Region, the Kunlun-Nanshan-Tsinling Fold System, and the Tibet-Yunnan Fold System - which have no equivalents in Australia. A major difference in China is the Mesozoic-Cainozoic deformation of much of the older units by events related to the Tethys-Himalayan Tectonic Domain, the Pal-Asiatic Tectonic Domain, and the

Marginal Pacific Tectonic Domain. Chinese tectonists make much use of lineament and fracture patterns and classifications of 'depth fractures', in explaining tectonic processes and tectonic evolution.

Chronostratigraphically they recognise major breaks in the Precambrian at about 2500 m.y., 1900 m.y., and 900 m.y. Lesser breaks occur at about 2000 m.y., 1700 m.y., 1400 m.y., 1100 m.y., and 700 m.y. The 10 000-m-thick Sinian Suberathem has a succession of platform-cover sequences ranging in age from 1900 m.y. to the base of the Cambrian. The Sinian System, about 900 m.y. to the base of the Cambrian, has well-developed glacial sequences, and resembles the Adelaidean of Australia. There are obvious similarities with the major breaks recognised in Australia, but the actual sequences observed in the field had little in common with those of similar age in Australia. The impression was gained that the time breaks in the Sinian were much longer than Chinese geologists believe. Chinese observational and field geology is of high quality, but isotopic age determinations, in common with other studies dependent on technology, are in their infancy and commonly based on minerals of suspect value. Much more work is required before the age ranges of their sequences are adequately defined.

VISIT TO THE BUNDESANSTALT FÜR GEOWISSENSCHAFTEN UND ROHSTOFFE (BGR), HANNOVER, FEDERAL REPUBLIC OF GERMANY, by R.J. Tingey

Tingey visited the BGR, the Federal German Government's national geological agency, in Hannover, West Germany, in June to describe Australian geological experience and results in Antarctica, and discuss plans for Federal German involvement in Antarctic Scientific Research. The visit was arranged under the Australia-Federal German science agreement.

Federal German scientists have participated in the Antarctic programs of other nations on an individual basis for some years but a direct Federal German involvement is now impending. The main interest is in the international BIOMASS marine biology project, in particular the krill '*Euphausia superba*', but Earth-science programs at sea and on land are also planned. Tingey reviewed outstanding geological problems in East Antarctica, and described Australian field methods in Antarctica, in particular the use of small light turbine helicopters such as the Hughes 500.

IRIAN JAYA GEOLOGICAL MAPPING PROJECT SECTION

Head: D.B. Dow

IRIAN JAYA GEOLOGICAL MAPPING PROJECT SECTION

by

D.S. Trail

The primary objective of the project is to assist Indonesia to strengthen institutional long-term capacity to undertake systematic and comprehensive geological and geophysical surveys and to produce maps and reports of appropriate quality.

The secondary objective of the project is to assist in systematic geological and geophysical surveys of the province of Irian Jaya (Fig. IJ1) as a means of providing the Indonesian Government with information necessary for the planning of earth resource management and utilisation; to date, the project manager, four BMR geologists and a geophysicist, have been appointed between July-September 1978.

A Record of Understanding was signed on 20 July 1978 between the Australian Development Assistance Bureau and the Department of National Development whereby the Department, operating through the Bureau of Mineral Resources, is to provide management of and certain services relating to the project.

In August 1978 the former Geological Survey of Indonesia (Direktorat Geologi) was re-organised; the former Geological Mapping Division became a separate directorate, the Geological Research and Development Centre or PPPG (Pusat Penyelidikan Perkembangan Geologi), which will be Indonesia's Managing Agent for the project.

GEOLOGICAL INVESTIGATIONS

by

D.S. Trail

STAFF: P.E. Pieters, G.P. Robinson, R.J. Ryburn, D.S. Trail*, C. Pigram

Using field equipment supplied by Australia, a party of Indonesian geologists and assistants undertook and completed 1:250 000 scale geological mapping of Biak, Supiori and other nearby islands between mid-October and the end of December, 1977 (Fig. IJ2). Trail and Pieters assisted this party and supervised the use of the equipment in October and November. Compilation of a special 1:250 000 geological sheet covering these islands was later undertaken in Bandung.

*Supervising Geologist, Australian Development Assistance Bureau, until September, 1978.

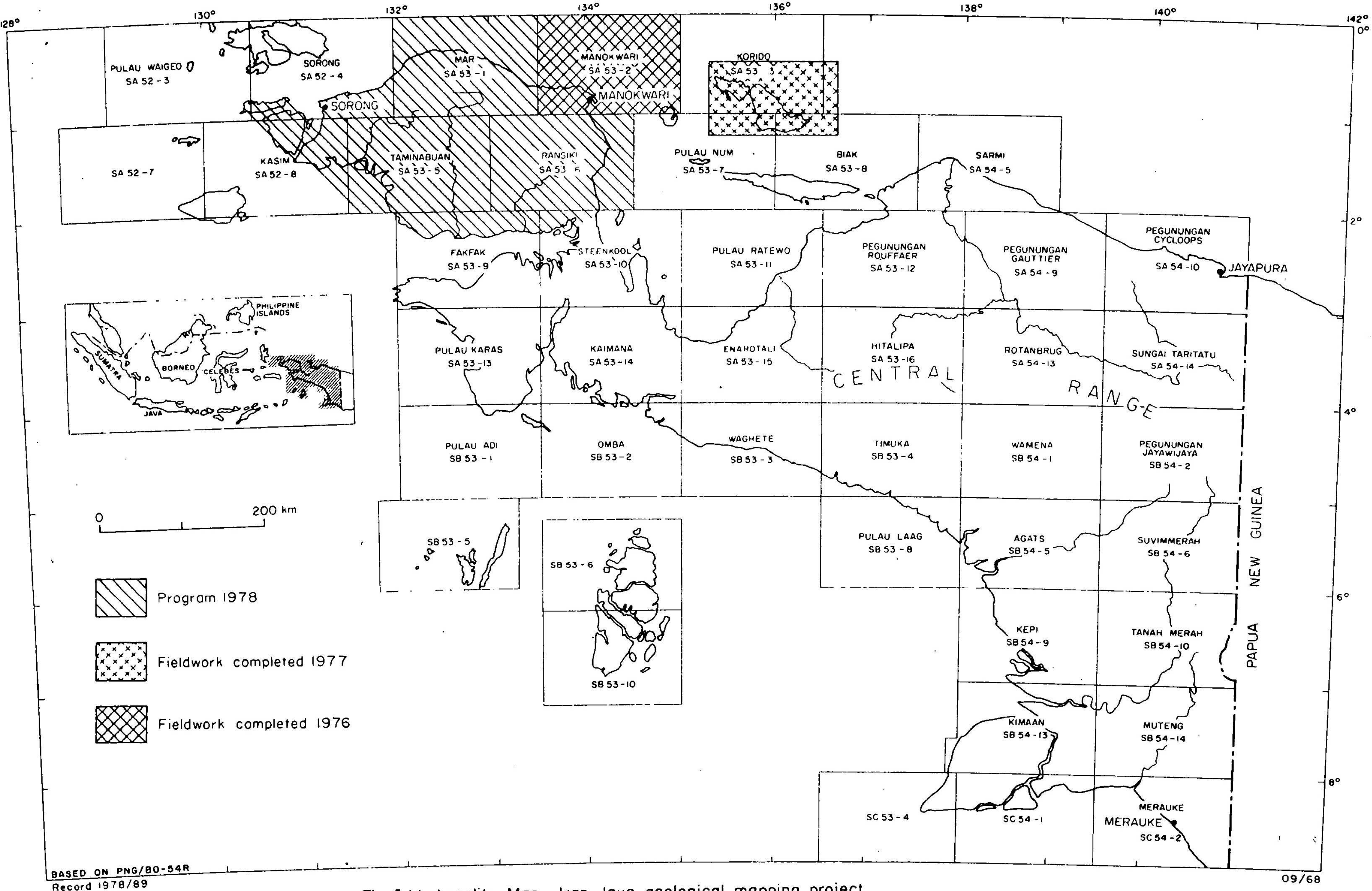
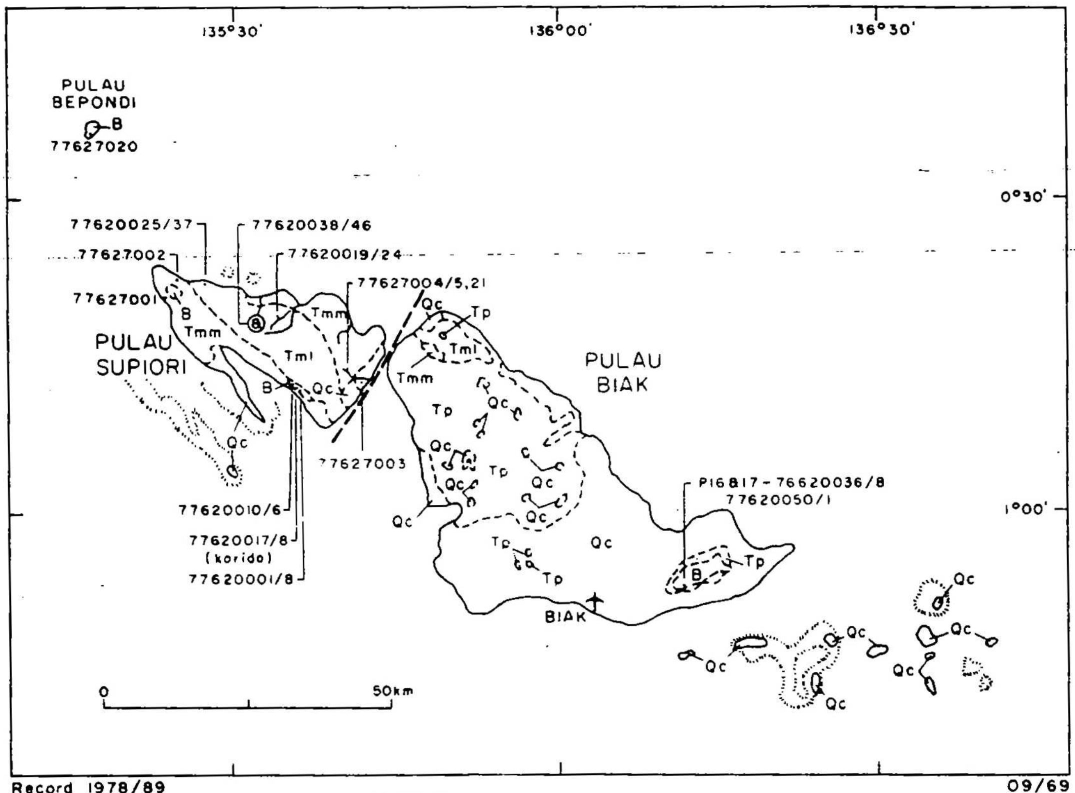


Fig. IJ1 Locality Map, Iran Jaya geological mapping project.



QUATERNARY	Qc	*Coral limestone and chalk*
UPPER MIOCENE TO PLIOCENE	Tp	*Chalky marl with interbeds of limestone and sandstone*
UPPER OLIGOCENE TO MIDDLE MIOCENE	Tmm	*Marls with interbedded fossiliferous limestone, greywacke sandstone and conglomerate*
UPPER OLIGOCENE TO MIDDLE MIOCENE	Tml	*Fossiliferous limestone*
BASEMENT, AGE UNKNOWN	B	*Metavolcanics, serpentinite, and basalt and gabbro*
	------	*Geological boundary*
	— — —	*Fault*
	P16 - 76620036	*Sample locality with fieldbook and rock sample reference number*
	Ⓐ	*Sample locality for K-Ar age determination*
	✈	*Airfield*

Fig. IJ2 Geology of Kepulauan Schouten.

Biak, the largest of the islands, is essentially a platform of raised Quaternary coral limestone around a core of Upper Miocene to Pliocene marl. Supiori Island is separated from Biak by a northwest-trending transform fault and is composed of Upper Oligocene to Middle Miocene marl and limestone with some clastic sediment. Basement consisting of metavolcanics, serpentinite, basalt and gabbro comprises scattered small outcrops on Biak, Supiori and Bepondi Islands. A single whole rock K/Ar age of 391 ± 30 m.y. (early Devonian) obtained from a basement gabbro may be anomalously high as the rock has an extremely low potassium content.

A second party from the Geological Survey of Indonesia undertook 1:250 000 scale geological mapping in northeast Irian Jaya in 1977, in the Pegunungan Cycloops and Sarmi sheet areas (Fig. IJ1). Samples collected by Pieters while visiting the area yielded early Miocene K/Ar ages (20.6 ± 0.4 m.y. and 21.4 ± 0.4 m.y.) for muscovite from schist and gneiss.

In June 1978 an Indonesian party began geological ground traversing on the Mar 1:250 000 sheet area in the western part of Irian Jaya. Robinson joined them in July to supervise and assist compilation of field data until the party returned to headquarters (Bandung) early in September.

D.B. Dow, as Project Manager, visited Jakarta and Bandung in August to conclude a contract with Pelita Air Service for the hire of two light helicopters for three months. He also discussed administrative procedures for the project with Australian Embassy staff. An Australian/Indonesian geological party comprising Dow, Robinson, Pieters and four Indonesian geologists commenced the 1:250 000 scale mapping of the Birdshead Peninsula late in September, using two Hughes 500 helicopters for transport.

The party was augmented in October by Ryburn and Pigram and the helicopter survey will continue until 18 December, 1978, during which time the Mar, Ransiki and Taminabuan sheet areas should be covered, together with small areas on adjacent sheets.

Pieters and Ryburn earlier prepared the text of a Record on a geological reconnaissance in Irian Jaya in 1976 and 1977 and Ryburn, assisted by the BMR computing group, investigated the feasibility of automatic processing of data to be collected during the current survey including the installation of a mini-computer in Bandung and the use of an offline terminal in the field. Draft tender specifications for the computer equipment have been compiled, and it is expected that this equipment will be installed in Bandung early in 1979.

S.K. Skwarko undertook the initial steps to establish a Mesozoic Macrofossil Study Group, within the Palaeontology Section of PPPG, in Bandung. It is planned to commence this group in April 1979, with an Australian geologist as a technical expert to advise on planning and scientific aspects of the work; it should consist of three Indonesian palaeontologists plus supporting staff.

GEOPHYSICAL INVESTIGATIONS

by

B.C. Barlow

STAFF: B.C. Barlow

During project feasibility studies it was decided that reconnaissance gravity and magnetic surveys should be carried out to make more effective use of the helicopter transport which would be needed in Irian Jaya for the proposed geological mapping and to provide the Geological Research and Development Center with training in reconnaissance geophysical surveying techniques.

It is proposed to cover the whole of Irian Jaya with the exception of two map sheet areas on the northern part of the PNG border. The reconnaissance geophysical surveys will share logistical support with the geological survey in the northern half of Irian Jaya. In the southern half the geophysical survey will need to be self-supporting.

The minimum coverage proposed is gravity and total field magnetic observations on a grid approximately 11 km x 11 km as has been achieved in Australia. In target areas revealed by the reconnaissance coverage or geological mapping, follow-up geophysical work is envisaged. Such semi-detailed or detailed work could include other geophysical techniques as appropriate; palaeomagnetic work is already planned for 1979.

Purchase of all equipment for the gravity and magnetic survey will be funded by ADAB, and specialist groups will be brought in on short-term assignments as necessary. The supervising geophysicist and senior technical officer will provide the Indonesian staff with training, guidance and supervision throughout the surveys, interpretation of data and reporting of results for geophysical and geodetic applications.

In October 1978 the chief geophysicist of PPPG joined Barlow in a reconnaissance gravity and magnetic survey. The helicopter-supported geophysical survey will begin in 1979.

MULTIDISCIPLINARY PROJECTS

Program Manager: A.R. Jensen

GEORGINA BASIN PROJECT

Compiled by

E.C. Druce (Project Co-ordinator)

STAFF: J. Draper (until April 1978), E. Druce, *J. Giddings (part time), *P. Harrison, K. Heighway, *M. Idnurm (part time), P.J. Jones (part time), *K. Jackson (part time), J. Kennard, *S. Mathur (part time), B.M. Radke (study leave), *J. Rees (part time), J. Shergold, C. Simpson (part time), *D. Tucker (part time), M. Walter (part time), R.G. Warren (part time), Gavin Young (part time) and B. Wyatt (part time), P.J. Kennewell (until June 1978), P. Green (GSQ), P. West (ANU), P. Kruze (Sydney University) and R. Fortey (British Museum).

Research is aimed at increasing our understanding of the geological history of the basin. This research into the distribution of the lithological units in time and space will aid exploration for hydrocarbons, phosphate, and base metals. Studies were undertaken in geophysics, geochemistry and geology by a multidisciplinary semi-autonomous team of specialists. (For relationships between stratigraphic units mentioned in text see Figs D1 and D2).

WORKSHOPS

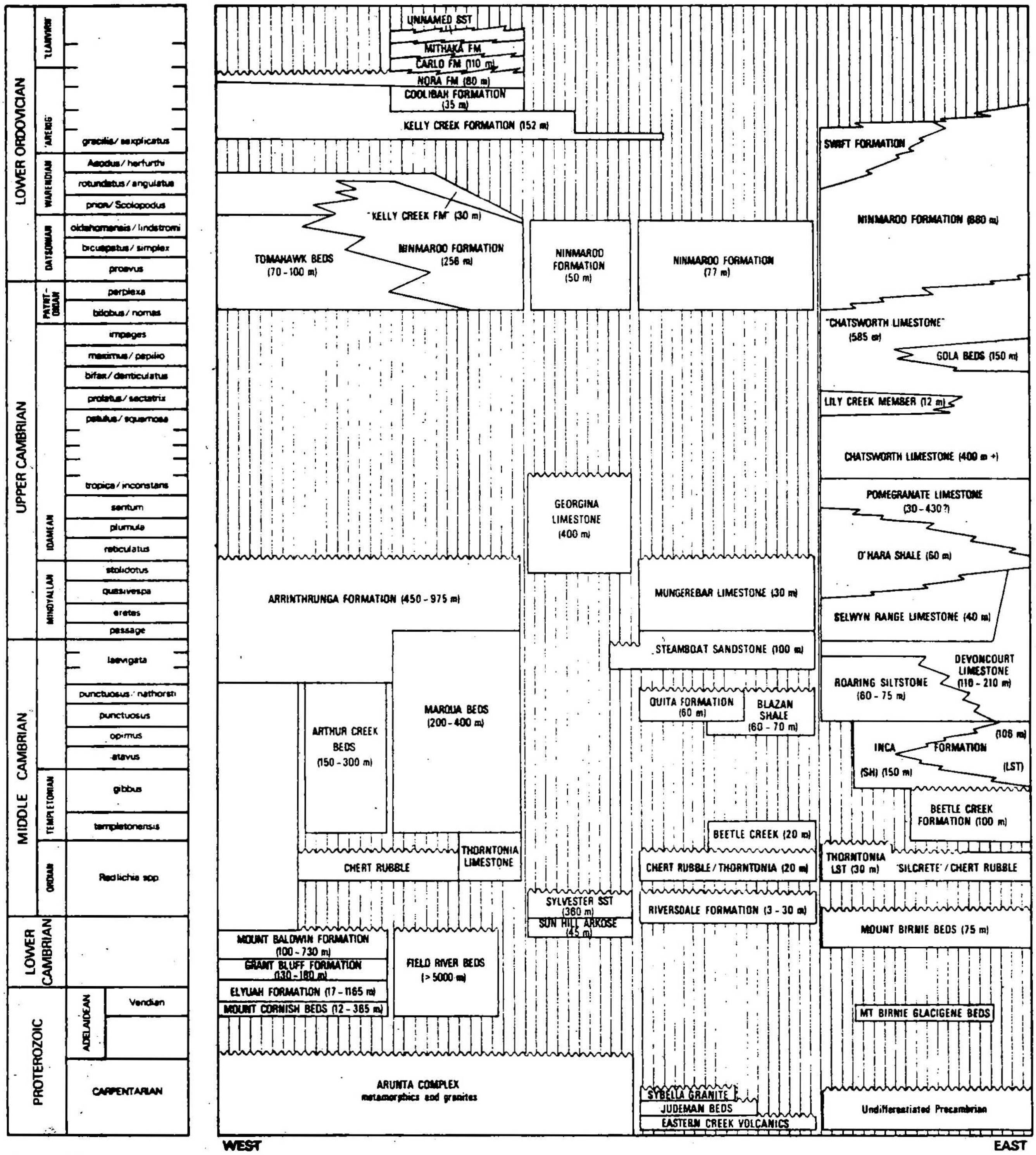
A Georgina Basin workshop was held during the 7th BMR Symposium (April 1978) which was attended by 56 people. The latest research results of the BMR project were presented for discussion and critical comment (E. Druce).

The inaugural field workshop and seminar of IGCP Project 156 (Phosphorites: Proterozoic/Cambrian of Australia and Asia) was held in August 1978. Some 58 scientists from 12 countries attended a field workshop in the Georgina Basin (J. Shergold).

SEISMIC RESEARCH

Seismic research involved a detailed interpretation of the Toko Syncline using seismic and gravity data collected during the 1977 field season.

*BMR officers, not members of Geological Branch



Record 1978/69

Fig.D1. Relationship of stratigraphic units on an east-west traverse across the northern part of the Georgina Basin at about latitudes 19° – 20°S

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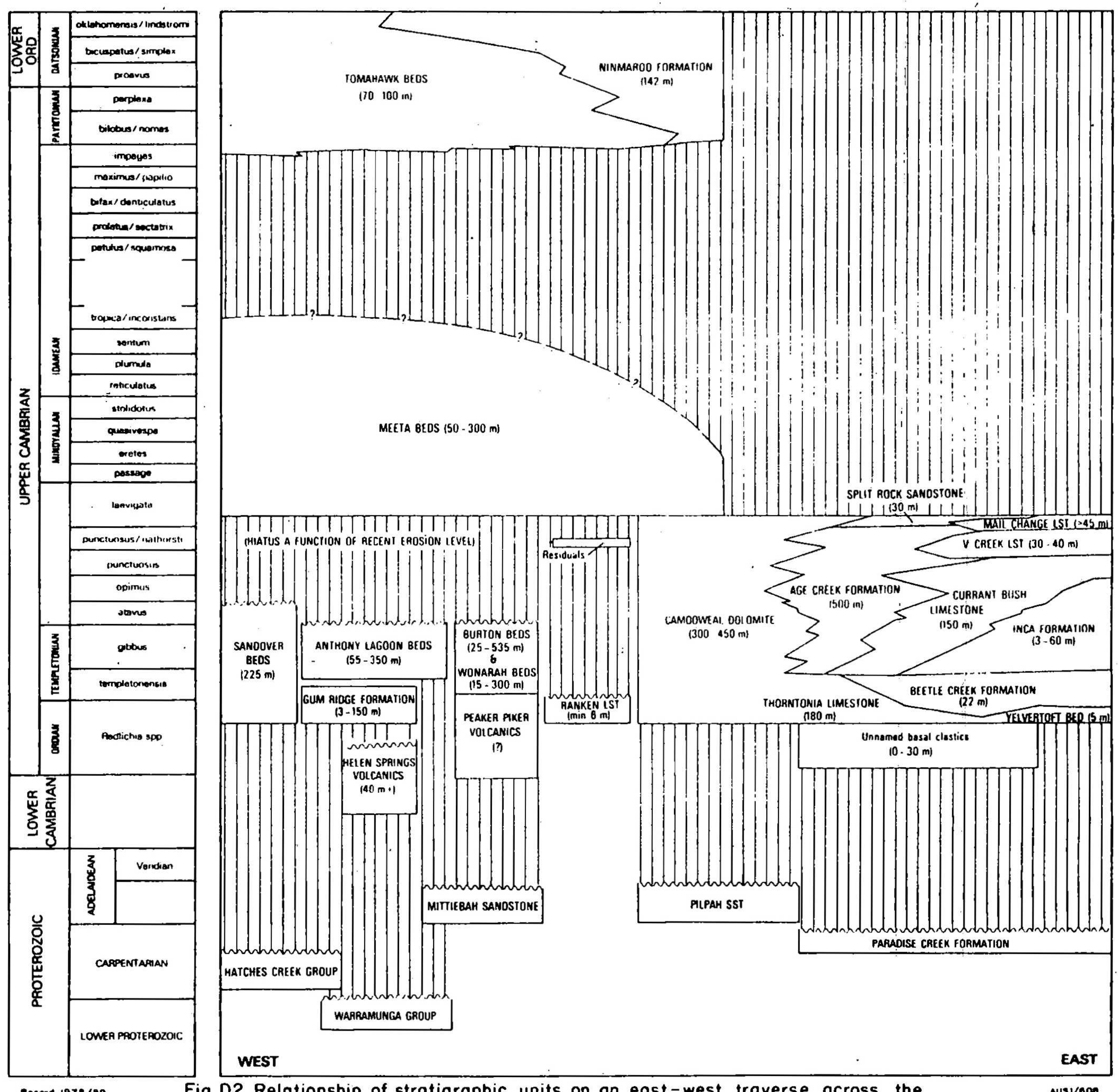

Fig.D2 Relationship of stratigraphic units on an east-west traverse across the southern marigin of the Georgina Basin at about latitudes 22°–23°

The Toko Syncline is a downwarp with a thrust faulted western margin (Toomba Fault). The fault is generally a high angle reverse fault and several seismic lines show reflections from bedded units beneath shallow basement - gravity studies confirm the presence of Arunta basement overlying Palaeozoic sediments. Within the syncline three major reflectors have been identified: the base of the Cambrian, the top of the Georgina Limestone (U. Cambrian) and the top of the Kelly Creek Formation (L. Ordovician). Structure contour maps for the top of the Georgina Limestone show a large structure, closed against the Toomba Fault, which includes the Ethabuka and Mirrica structures partly delineated by Alliance Oil Development. This structure has a minimum closure of 700 m over an area of about 130 km^2. A study of the stratigraphy shows that the southeast plunge was caused by tectonic activity rather than syndepositional subsidence although there is some southerly thickening of the Ordovician sequence. A 400 m thick southeastward prograding sequence, identified on the seismograms, is considered to represent the Steamboat Sandstone. Within the Middle Ordovician "Ethabuka Beds" an unconformity has been recognised on the seismic records which ties to an unconformity at 1024 m in Ethabuka No. 1 well (P. Harrison).

GEOPHYSICAL ANALYSIS OF BASEMENT

A basin-wide study of the pre-Phanerozoic crustal geology is in progress. Preliminary results show that there are four regions with differing anomaly characteristics based on gravity and magnetic data. This division comprises regions which are: Arunta-like, comprising the westerly and southerly parts of the Basin; Mount Isa-like, essentially the eastern margin; Lovelle-like along the south-eastern rim; and Intermediate, a zone between the Arunta-like and Mount Isa-like regions which appears to be an extension of the zone of high Bouguer anomalies associated with the Musgrave Block. Lateral composition changes in Precambrian rocks are primarily responsible for variation in the gravity and magnetic pattern: the Toko Syncline is an exception with a thick sequence of Adelaidean and Palaeozoic sediments causing a elongate gravity low. Two major magnetic gradients are present in the southerly part of the basin and both are attributed to reverse faulting. An east-west gradient in the southern part of the Tobermory and western part of Mount Whelan 1:250 000 Sheet areas probably represents a low angle (15^{o}) thrust sheet at a depth of 4-6 km. The thrusting is to the north and partially coincides with the Craigie Fault, suggesting that the Craigie Fault is, in part, caused by reactivation along an older thrust plane. The second gradient is in the southeasterly part of the Basin and forms the boundary between the Mount Isa-like and Lovelle-like regions. It is considered to be a high angle reverse fault with overthrusting to the south: in part the modelled fault coincides with the Cork Fault (D.H. Tucker, B. Wyatt, S. Mathur, E. Druce).

GEOCHEMICAL RESEARCH

Both organic geochemistry and regional whole rock geochemical studies are in progress. Regional geochemical investigations have demonstrated that strontium, iron and manganese are the best elements for the geochemical discrimination of rock units and for the interpretation of depositional environments. The Upper Cambrian Arrinthrunga Formation has high fluorine values and sphalerite is present in minor quantities (J. Draper).

Source rock studies continued and nine samples from Brothers No. 1 and Netting Fence No. 1 wells were analysed by Esso Australia from core material held by BMR under the Petroleum Search Subsidy Act. Total organic carbon figures suggest that possible source rocks are rare apart from a horizon at 1955.6 m (6416 feet) in Netting Fence No. 1 well (?Middle Cambrian Marqua Beds). Thermal indices measured vary from 2.5 to 3+ although no systematic down hole increase is apparent. The latter values indicate over-maturity, the rocks having passed through the oil generating stage. The C15+ analysis on the sample from 1955.6 suggests that it is a good oil source and some liquid hydrocarbons may have been generated because there is oil staining at 1882.4 m (6176 feet) within the presumed Marqua Beds (K. Jackson).

SEDIMENTOLOGICAL AND STRATIGRAPHIC RESEARCH

Basement rocks exposed at the southern limit of Palaeozoic sediments are representative of the Arunta Block comprising two metamorphic units intruded by four different granites. Age determinations (1725 m.y., 1719 m.y., and 1662 m.y.) based on K-Ar ratios from muscovite in granite and co-eval pegmatites, are considered to represent the age of initial crystallization implying that Arunta Block rocks east of the Tarlton Fault have not been affected by post Carpentarian (post 1700 m.y.) metamorphic events (R.G. Warren).

A small inlier of basement rock has been discovered on the Mount Whelan Sheet area, 22 km southeast of Sun Hill. Very weathered granitic material similar to granites within the Arunta Block on the Hay River Sheet area is overlain by arkose and shale (C.J. Simpson and J.H. Shergold).

Further examination of Adelaidean sediments in the Sun Hill-Watchie Hut area (Mount Whelan Sheet area) has shown that:

- lithologically the Sun Hill Arkose is more similar to the Black Stump Arkose than the Gnallan-a-gea Arkose (of the Hay River Sheet area);
- the Pb and Ag bearing arkose at Watchie Hut is probably Sun Hill Arkose - it is overlain by dolomitic grit, dolarenite and sandy dolostone which may be equivalent to the Wonnadinna Dolomite (Hay River Sheet area);
- the tillite at Duchess is overlain by a dolostone and shale sequence, unlike the cap rock of the tillite on the Hay River Sheet area, and is considered to be a younger tillite (C.J. Simpson).

The stratigraphy of the Adelaidean rocks, the oldest sequence in the Basin, has been further elucidated and the former Field River Beds have been divided into six formations. The tillite in the Hay River Sheet area ("Yardida Tillite") has been shown to be equivalent to the lower of two tillites generally present in central Australia. The "Yardida Tillite" is unconformably overlain by the Field River Group which includes arkose, siltstone and dolomite units some 1300 m thick. The overlying Grant Bluff Formation is a correlative of the Cyclops Member of the Pertatataka Formation of the Amadeus Basin and there is now considered to be a longer time break between the Precambrian and the Cambrian in the southern part of the Basin than elsewhere in central Australia (M.R. Walter).

The Grant Bluff Formation is unconformably overlain by "Desert Bore Beds" and the unconformity is marked by silicification and the development of quartz crystals with fluid inclusions some of which contain hydrocarbons - the minimum temperature of formation is considered to be in the range 76°C - 93°C (C. Simpson).

The carbonates of the Upper Cambrian Arrinthrunga Formation cover a wide spectrum of petrographic types, the most predominant being peloidal and ooid grainstone, algal boundstone, mudstone and crystalline dolostone. The sequence represents deposition in shallow subtidal, intertidal and locally supratidal environments. There is a general shallowing of water depths from the southeast to the northwest, and this trend is paralleled by an increase in the proportion of dolomite and terrigenous sand and shale. Evaporites (gypsum, halite and ?anhydrite), fluorite and occurrences of galena and sphalerite are restricted to the west and northwest.

A karst erosion surface has been identified between the Arrinthrunga Formation and the overlying sandstones of the Tomahawk Beds: diagnostic features include laminar and pisolitic calcrete, cavity fill breccia, an irregular topographic surface overlain and infilled by sandstone, and the disruption of drainage and joint patterns near the contact. Two solution collapse cauldrons after evaporites are present within the Eurowie Sandstone Member 3.2 km NNE of Eurowie Yard (Huckitta Sheet area); they are 80 - 120 m in diameter and filled with jumbled sandstone blocks up to 20 m long. Examination of core from BMR Huckitta No. 1 (formerly Grg No. 1) and BMR Elkedra No. 5 (Grg 5) has shown that the sequences in both holes represent the Arrinthrunga Formation rather than the Tomahawk Beds as originally proposed. Thus the distribution of the Arrinthrunga Formation has been extended westward to the edge of the Huckitta Sheet area and northward to near the southern margin of the Precambrian of the Hatches Creek area (J. Kennard).

The Lower Ordovician Kelly Creek Formation in the Tobermory Sheet area comprises a lower sandstone unit (with tracks, trails, and burrows) and an upper dolomitic unit, informally designated the "Withillindarmna Dolomite". This latter unit interfingers with the overlying Coolibah Formation in the central part of the Sheet area. Farther west the Kelly Creek clastic unit becomes gypsiferous and both the "Withillindarmna Dolomite" and the Coolibah Formation become progressively more clastic: at the southern end of the Tarlton Range rocks with a fauna similar to the Coolibah Formation are cross bedded sandstones which are included in the Kelly Creek Formation. The Kelly Creek Formation straddles the Tremadocian/Arenigian boundary and may be both conformable and unconformable on the underlying dolomitic units of the Ninmaroo Formation. The Tomahawk Beds comprise clastic rocks coeval with the Ninmaroo Formation (carbonates) and Kelly Creek Formation. In the Huckitta Sheet area there are three distinct units: a lower richly glauconitic sandstone, a middle calcareous and peloidal sandstone, and an upper sandstone with a rich ichnofauna. The latter is indistinguishable from the Kelly Creek Formation (E.C. Druce).

The Lower to Middle Ordovician Mithaka Formation, which is confined to the Toko Syncline, comprises dark grey pyritic mudstone with numerous thin lensoid sandstone interbeds; it is bioturbated and contains rare phosphatic pellets. The fauna and lithology are consistent with sedimentation in a lagoon as postulated in the sedimentary model proposed for the underlying Carlo Sandstone (J.J. Draper).

PALAEONTOLOGY

The stromatolite Acaciella australica Walter has been found in the Adelaidean "Yackah Beds" of the Hay River sheet area, supporting the correlation of those beds with the Bitter Springs Formation of the Amadeus Basin (M.R. Walter).

Archaeocyathids from the Lower Cambrian "Desert Bore Beds" of the Hay River Sheet area indicate an Atdabanian - early Lenian age (in terms of the Siberian stages) and a correlation with the Mount Baldwin Formation (P. Kruse).

The conodont Clavohamulus primitus Miller has been recovered from the Lower Ordovician Ninmaroo Formation in the Burke River Structural Belt and the Tobermory Sheet area: its presence, together with Cordylodus proavus, provides a much firmer correlation of Australian Tremadocian sequences with those in North America (E.C. Druce).

Trilobites from the Lower Ordovician Nora Formation indicate that the unit spans nearly all the Arenigian. The faunas are characterised by endemic species belonging to families which existed in the Late Cambrian together with some extra-Austral forms which may provide a basis for correlation with northern hemisphere sequences (R. Fortey and J. Shergold).

The Wuttagoonaspis fauna has been recovered from the Devonian Cravens Peak Beds (sandstones) together with several new placoderms resembling forms from the lower part of the Dulcie Sandstone. An unnamed limestone unit on the western margin of the Toko Suncline has yielded abundant onychodontid crossopterygian remains (teeth, scales, fin rays) tentatively referred to Onychodus sp. together with rare placoderm plates and acanthodian spines (G.C. Young).

The limestone unit has also yielded thelodont scales - Turinia australiensis Cross and T. pagei (Powrie) - abundant eridostracans (Cryptophyllus) and some ostracods. The thelodont scales indicate an Early Devonian (Dittonian) age whereas Cryptophyllus sp A. Jones 1962 suggest that the unit could be as young as Late Middle/earliest Late Devonian (P.J. Jones, J.J. Draper and Susan Turner, Hancock Museum, UK).

Trilobites from the Upper Cambrian Chatsworth Limestone have been described: they are post-Idamean but pre-Payntonian in age and have affinities with faunas from northern China, Korea, the north Siberian Platform and Kazakhstan (J, Shergold).

PALAEOMAGNETISM

Samples from tillitic beds in the Georgina Basin were analysed to determine their palaeomagnetic character. There is a distinct grouping of measurements around a shallow westerly inclination: a result which is consistent with measurements from the Areyonga Formation of the Amadeus Basin and from the Tapley Hill Formation and Merinjina Tillite of the Adelaide Geosyncline (M. Idnurm).

ECONOMIC GEOLOGY

Numerous clasts of galena and tourmaline-quartz rock have been observed at a locality within the Adelaidean Oorobra Arkose near Oorobra Rockholes in the Huckitta Sheet area. These had previously been noted by Brown (1896). The galena clasts are poorly sorted, are 2-12 cm in size and, considering the fragile nature of the 5-15 mm galena crystals, have undergone minimal transportation. Regionally the arkose occurs as isolated wedges resting directly on the eroded surface of the Proterozoic Jinka Granite. The arkose comprises pebbles and cobbles of the granite and it is probable that the galena source is within the granite (J. Kennard and M.R. Walter).

A petroleum resource assessment of the Mirrica-Ethabuka structure was undertaken: the probability of occurrence of critical factors was estimated to be - reservoir (0.8 probability) source rocks (1.0), necessary thermal history (1.0), effective trap and seal (0.4), correct timing (0.9), absence of flushing (0.8). Conodont maturation indices indicate that the reservoir is gas prone and the estimated chance of gas discovery is about one in four. Should gas be present there is a 95% probability of recovering 0.6 trillion cubic feet and a 5% chance of recovering 3.2 TCF: the mean recoverable reserves are estimated to be 1.5 TCF (P. Harrison, E. Druce, K. Jackson, and E. Riesz and D. Forman, Petroleum Exploration Branch).

McARTHUR BASIN PROJECT

Compiled by

K.A. Plumb

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*BMR officers, not members of Geological Branch

The basic aim of the McArthur Basin Project is to elucidate the evolution of the McArthur Basin, using stratigraphic, sedimentological, geochemical, tectonic, and other studies and to apply this information so as to understand the genesis of ore deposits in the region.

OBJECTIVES OF 1978 PROGRAM

The main objectives of the 1978 program were:

(1) Commence a study of the sedimentology and palaeogeography of the Wollogorang Formation, Masterton Formation, Mallapunyah Formation, and Amelia Dolomite.

(2) Commence a study of the sedimentology, palaeogeography, and micro-palaeontology of the Balbirini Dolomite, Dungaminnie Formation, and their stratigraphic equivalents.

(3) Undertake field research on the geology of the Mallapunyah-Kilgour 1:100 000 Sheet area and parts of adjoining areas, at photo-scale (1:25 000).

(4) Complete laboratory measurements on 1977 magneto-stratigraphic reconnaissance samples from the McArthur Basin.

(5) Make further detailed collections of magneto-stratigraphic samples in order to (a) determine the magneto-stratigraphic column of polar reversals through the McArthur Basin, as an aid to chronostratigraphic correlation, and (b) determine the polar wander curve for the Carpentarian.

(6) Carry out detailed magneto-telluric and gravity surveys along a profile across the Wearyan Shelf and eastern Batten Fault Zone, to determine the applicability of the methods to (a) defining the configuration and depth of basement beneath the McArthur Basin, (b) defining thickness variations within the basin succession, (c) locating and defining the form of major structures, with the immediate aim of defining the basement and McArthur Basin succession beneath concealed areas of the Wearyan Shelf, immediately to the east of the Emu Fault.

SYSTEMATIC MAPPING M.J. Jackson (Task Leader)

Mapping of the Mallapunyah-Kilgour 1:100 000 Sheet area was almost completed (Fig. D3). Photo-scale compilations of the area mapped are almost complete.

The principal changes made to the existing 1:250 000 geological maps are:

(1) Areas previously thought to be Emmerugga Dolomite have now been subdivided into Mara Dolomite Member, Mitchell Yark Dolomite Member, Teena Dolomite, Coxco Dolomite Member, Barney Creek Formation, and Reward Dolomite (K.A. Plumb, C.J. Simpson, M.D. Muir);

(2) Areas previously shown as Billengarrah Formation, in the area studied, have been shown to consist of Balbirini Dolomite and Dungaminnie Formation (M.D. Muir, K.A. Plumb);

(3) A new basin of Roper Group rocks has been identified in the south, between Top Springs homestead and the Mallapunyah Dome (M.D. Muir, M.J. Jackson);

(4) New understanding of the stratigraphy of the McArthur Group has allowed radical revision of the map along the Kilgour River, around the southeastern end of the Abner Range (M.D. Muir).

REGIONAL STRATIGRAPHIC AND STRUCTURAL STUDIES

TAWALLAH GROUP (M.J. Jackson)

Tawallah Group rocks are exposed in three meridionally-trending structural highs at the southern end of the area mapped. Detailed mapping has better defined their distribution and shown that the rocks are more intensely faulted than previously thought. New information resulting from this work is summarised below:

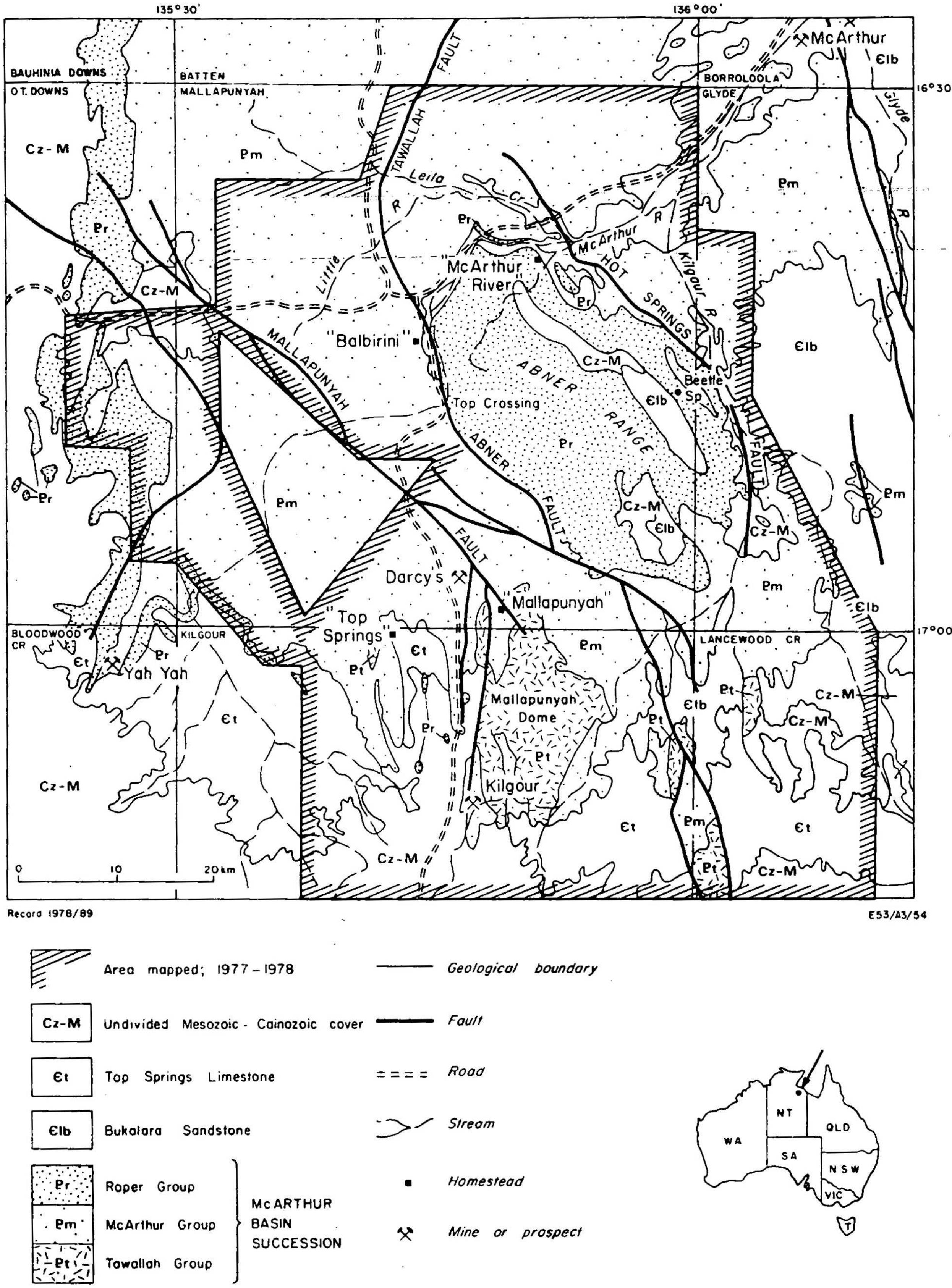


Fig D3 Generalised geological map and progress of mapping — McArthur geological research, 1978.

1. The McDermott Formation consists mainly of massive recrystallised red carbonate rock lacking obvious sedimentary or algal structures. It differs noticeably from carbonate rocks found in the remainder of the McArthur Basin sequence.

2. Glauconite has been found at several localities in the Mallapunyah Dome, within rocks previously mapped as Sly Creek Sandstone; they should therefore be reassigned to the Rosie Creek Sandstone. Gypsum pseudomorphos have been identified in the unit.

3. The Gold Creek Volcanic Member (of the Masterton Formation) has been identified throughout the southern area. It is usually emplaced at or near the base of the Masterton Formation, but has been found intruding the Wollogorang Formation. Together with the Wollogorang Formation , the Gold Creek Volcanic Member forms an attractive mineral prospect, as both units contain widespread disseminated lead, zinc, and copper mineralisation.

4. A distinct break has been identified between the Wollogorang Formation and the overlying sandstone member of the Masterton Formation. This observation adds new confirmation of the unconformity predicted at the base of the Masterton sandstone unit in recent publications by Plumb.

McARTHUR GROUP

The Mallapunyah, Tawallah, and Hot Springs Faults are now shown to have been important hinge zones during deposition of the McArthur Group. New erosion breaks or unconformities have been identified or confirmed at several levels within the McArthur Group. Widespread karstic features, of several ages, have been identified in several rock units, and are important to the interpretation of the evolution of the basin and the origin of mineralisation.

Unconformities (M.D. Muir, K.A. Plumb)

To the southeast of the Abner Range, erosion breaks and unconformities have been identified at the base of the "Lower Lynott" Formation and Yalco Formation. An unconformity occurs between the "Lower Lynott" and "Upper Lynott" Formations around the northern end of the Abner Range.

A regional unconformity occurs at the base of the Balbirini Dolomite, which rests directly on all units down to the Reward Dolomite.

The regional unconformity at the base of the Limmen Sandstone cuts out most of the Dungaminnie Formation/Balbirini Dolomite succession on the eastern and southern sides of the Abner Range.

Karstic Features (M.D. Muir, K.A. Plumb)

Many types of karstic features have been recognised in carbonate-rich units: vertical-zoned veins; breccia-filled veins, cavities, and caves; sinkholes; irregular upper surfaces grading into tower karst; silicified upper surfaces; recrystallisation of carbonates to coarse-grained, equant dolomite and siderite. They are particularly characteristic of the Mitchell Yard and Coxco Dolomite Members and the Reward Dolomite. They have probably been formed during several periods of exposure and erosion.

In the less well exposed areas to the north, it is usually not possible to separate fossil karst features from those related to Cainozoic erosion surfaces, but in the better dissected areas to the east of the Abner Range fossil karst surfaces have been identified.

Fossil karst may be related to: the pre-Bukalara Sandstone (Early Cambrian) surface; the pre-Limmen Sandstone surface; the pre-Balbirini Dolomite surface; the pre-Yalco Formation surface; the pre-"Upper Lynott" Formation surface. The age of karsting on the Mitchell Yard and Coxco Dolomite Members is problematical.

Mineralisation (M.D. Muir)

The unconformities and karstic surfaces are commonly marked by the presence of thin, generally siliceous ironstones, and trace to fairly large amounts of secondary copper minerals, mainly malachite, are common in the underlying rocks. This is particularly apparent at the Reward Dolomite/Balbirini Dolomite unconformity: small caves in the Reward Dolomite can be wholly or partly filled with malachite and chrysocolla (e.g., Yah Yah and Darcy's copper prospects), and copper traces always occur where the Balbirini Dolomite overlies the stromatolitic facies of the Reward Dolomite.

Traces of chalcopyrite occur at the Yalco Formation/Balbirini Dolomite unconformity south of the Abner Range, and traces of malachite have been found at the Balbirini Dolomite/Limmen Sandstone unconformity near Top Springs homestead. Traces of cuprite occur at the Leila Sandstone Member/ Bukalara Sandstone unconformity at William Creek, on the edge of the Bukalara Plateau.

A small cave-fill deposit of secondary copper minerals occurs at the contact between the Mara and Mitchell Yard Dolomite Members, in a heavily karsted area of unknown age near Tooganinie Creek (K.A. Plumb).

These karstic unconformities are clearly prospective, but large amounts can only be expected where suitable caves or open veins occur in the carbonate units. The source of the copper is not known.

Miscellaneous Stratigraphy

The area to the east and south of the Abner Range is much more complex, both stratigraphically and structurally, than previously mapped. The Hot Springs Fault is the axis of several significant facies changes.

The subunits of the Emmerugga Dolomite, Teena Dolomite, and Barney Creek Formation retain their usual characteristics, as previously determined by M.C. Brown, throughout the area mapped (K.A. Plumb, M.D. Muir, C.J. Simpson). An important new feature is the discovery of pseudomorphs after evaporite minerals (acicular gypsum needles and prismatic laths after (?) gypsum) in the Mitchell Yard Dolomite Member (K.A. Plumb).

The Teena Dolomite and Barney Creek Formation show marked variations in thickness, with several sub-basins of relatively thick Barney Creek Formation. The Barney Creek Formation shows wide variations in carbonate, carbon, and iron content between different areas.

An important new discovery in the western area, around the upper Tooganinie Creek, is clusters of radiating acicular gypsum casts in the Barney Creek Formation, identical to those previously considered to be characteristic of the underlying Coxco Dolomite Member (K.A. Plumb, C.J. Simpson).

The Reward Dolomite varies widely in thickness and rock type throughout the area mapped; it is an excellent indicator of the overall tectonic setting of both itself and the underlying Barney Creek Formation. The massive carbonate-rich turbidite facies to the northeast of the Abner Range (measured section G1 of 1977 work) changes to a very thin stromatolitic facies, containing Conophyton and radiating acicular gypsum casts, between the Hot Springs and Tawallah Faults. Farther west massive coarse dolarenites characterise the unit. At the southern end of the Abner Range these facies occur together: turbities, overlain by stromatolitic dolomite, and dolarenite at the top.

All the shallow subtidal to supratidal facies which were identified in the Batten Subgroup during 1977 have been traced continuously throughout the area mapped during 1978. Redefinition of the turbiditic "Lower Lynott" Formation as a separate formation is warranted. The component units of the Batten Subgroup have now been identified and mapped within the "Billengarrah Formation" at Top Crossing, but outcrops of Batten Subgroup only continue for about 10 km west from Top Crossing (K.A. Plumb).

An important new result of mapping between Leila Creek and Top Crossing is the recognition that the Amos Formation and Looking Glass Formation are stratigraphic equivalents. Both are highly altered carbonate units: the Amos Formation may be a fossil calcrete, while the ubiquitous silicification of the Looking Glass Formation might be attributed to either early diagenesis or to silcrete formation on an emergent surface (K.A. Plumb, M.D. Muir).

Structure (M.D. Muir)

McArthur Group rocks are preserved in a series of structural basins separated by faults, except on the east and especially in the south of the Abner Range, where they are folded in a similar style to that of the overlying Roper Group; the Balbirini Dolomite is involved in this folding.

Elsewhere, to the south and west of the Abner Range, the Balbirini Dolomite and Batten Subgroup are unaffected by folding which affects the older formations of the McArthur Group, and overlie the folded sediments without disturbance.

ROPER GROUP (M.D. Muir)

Rocks from the Roper Group were mapped in the Abner Range and to the east of Top Springs homestead. In addition, core from a drill hole to the west of Bauhinia Downs Homestead was sampled, in Darwin, for micro-palaeontological and stratigraphic studies. This drill hole penetrated the Bessie Creek Sandstone, Corcoran Formation and Hodgson Sandstone Member (of the Abner Sandstone). Since the Corcoran Formation is everywhere poorly exposed, this drill core provides possibly the only complete section of the unit available.

To the east of Top Springs homestead, a sequence of rocks which were previously mapped as Billengarah Formation, Mallapunyah Formation, Masterton Formation, and Tatoola Sandstone have now been identified as Limmen Sandstone, Arnold Sandstone Member, and Hodgson Sandstone Member of the Roper Group. An undifferentiated Proterozoic sequence, to the south, has also been identified as the Abner Sandstone. Slightly to the north of this area, a sub-circular black-soil plain is rimmed by Limmen Sandstone, as if it may have been a large sinkhole (M.D. Muir).

Structure

In the Abner Range, the Roper Group is folded into a series of northwest-trending anticlines, synclines, and monoclinal flexures, parallel to the Hot Springs Fault. The Cambrian Bukalara Sandstone is involved in the same folding as the Roper Group in the Abner Range, but whether this indicates that the Roper Group sediments had not been folded prior to deposition of the Bukalara Sandstone, or that the old Precambrian fold axes were rejuvenated, remains to be seen. Elsewhere, the Bukalara Sandstone is flat-lying and strongly unconformable on the McArthur Basin rocks.

SEDIMENTOLOGICAL STUDIES

UPPER TAWALLAH GROUP - LOWER McARTHUR GROUP (M.J. Jackson)

Detailed sedimentological studies were commenced in the Wollogorang Formation, Masterton Formation, Mallapunyah Formation, and Amelia Dolomite, in the southern part of the area where the best exposures are found.

Wollogorang Formation

A lateral change from a quiet-water carbonate facies to a higher-energy more clastic facies was established in the lower part of the Wollogorang Formation, around the eastern and northern sides of the Mallapunyah Dome. Higher in the formation, uniform deposition in a quiet-energy environment is indicated. Disseminated copper mineralisation is widespread near the top of the unit.

Masterton Formation

Although only one detailed section was measured through the formation, it seems to be representative of the formation as a whole throughout the southern area. The sequence is interpreted as indicating a regressive sequence, from open marine, through intertidal shallow marine, to lagoonal environments. Ripple orientation and cross-stratification measurements indicate a wide range of current directions.

Mallapunyah Formation

The Mallapunyah Formation consists mainly of thin to medium-bedded dolomitic siltstone and silty dolomites, with interbeds of conglomeratic cross-'tratified silty sandstones. A lagoonal or flood plain type of environment is envisaged. Coarser spherical quartz grains may be of aeolian origin, whilst cross-stratified silty sandstones are probably from short-lived fluvial events. The well-known "cauliflower chert" nodules, after evaporite minerals, are diagenetic features.

Amelia Dolomite

The Amelia Dolomite is of uniform thickness and rock type throughout the whole of the southern area. It consists of interbedded stromatolitic and non-stromatolitic (pisolitic, oolitic, intraclastic, conglomeratic) dolostones, with gypsum and halite pseudomorphs at several different stratigraphic levels. Bioherms of Conophyton-like stromatolites may be traced for many tens of kilometres. Disseminated copper mineralisation was found in massive recrystallised stromatolitic dolomites in several sections.

UPPER McARTHUR GROUP (M.D. Muir)

Balbirini Dolomite

The almost 900 m-thick Balbirini Dolomite contains a number of well defined units. The lowermost unit is a red siltstone facies, of probable supratidal or terrestrial origin, but a coarse water-laid basal conglomerate occurs in some areas. The siltstone passes up into an evaporitic sequence containing a variety of pseudomorphs of: possible polyhalite; "cauliflower cherts"; discoidal, hexagonal prismatic, and equent seed gypsum; and sideritic or ferroan dolomitic marble after massive gypsum replacement of earlier carbonate.

The evaporite sequence is overlain by a stromatolitic unit containing several forms, but characterised by a laterally-persistent bed of a characteristic branching Conophyton. This unit is followed by a quartz sandstone sequence, which is capped by another stromatolite bioherm complex, characterised by a form of Kussiella.

The upper parts of the exposed sequence are dolarenites and flake breccias, with minor evaporites, and were deposited under shallow-water to desiccating conditions.

Dungaminnie Formation

This unit crops out only around the northern end of the Abner Range, and it is neither well-exposed nor well-preserved. The lower part of the section consists of siltstone, sandstone, and some stratiform-stromatolitic dololutite. Higher in the sequence there is a conspicuous but laterally impersistent bed of Conophyton, in which the columns are inclined at about 60^{o} to bedding. The highest part of the Dungaminnie Formation consists of rapidly-deposited detrital carbonate rocks and quartz sandstone.

REPORTING OF RESULTS

The results of the 1977 fieldwork have been described in Record 1978/54.

Record 1969/145, describing results of sedimentological and geochemical studies of the McArthur Group, by M.C. Brown and C.W. Claxton during 1967-68, has been released.

A paper describing microfossils from the Roper Group, by C.J. Peat, M.D. Muir, K.A. Plumb, D.M. McKirdy, and M.S. Norvick was published in volume 3 of the BMR Journal.

A systhesis of the evolution of the McArthur Basin - Mount Isa Region, by K.A. Plumb, G.M. Derrick and I.H. Wilson, was presented to the 3rd Convention of the Geological Society of Australia, and is now in press for publication, by the Society, early in 1979.

PALAEOMAGNETIC RESEARCH (M. Idnurm (Task Leader); J.W. Giddings)

Laboratory Measurements

The magnetostratigraphic reconnaissance study of the McArthur Basin, started in 1977, was completed. 85 pilot specimens had been collected from the Kilgour River area (measured sections K1-K12), at equal stratigraphic intervals through 1000 m of section, from the top of the Masterton Formation to the upper Emmerugga Dolomite. Duplicate sections were sampled in some cases.

After progressive thermal demagnetization had been carried out, up to the Curie Point of hematite, remanence intensities remained well above the sensitivity limit of the cryogenic magnetometer, and stable remanence directions were generally obtained. No secondary components, other than a pronounced Recent field component, were found.

A distinct polarity reversal pattern is emerging from these measurements and a tentative polarity reversal column has been drawn up. Tentative correlations can be made in each of the two cases where duplicate sections were sampled. The reconnaissance study clearly demonstrates that magnetostratigraphic correlation has definite potential in the McArthur Group and the uppermost Tawallah Group, if not in the McArthur Basin generally, and further work is warranted.

Significant polar wander is observed within the sequence. In particular, a large shift in the pole position appears to have taken place at about the Mallapunyah Formation-Amelia Dolomite boundary. Although this shift coincides with a general change in rock types, from dominantly siltstone to dominantly stromatolitic dolomite, the stratigraphic evidence suggests that the transition is gradational.

The pole positions also indicate that the region was at high (magnetic) latitudes during the deposition of the sediments (or strictly, during the acquisition of the primary remanence). This, again, is at variance with the abundance of evaporites and stromatolites in the sequence, which is usually taken to indicate a warm to hot climate.

A second reconnaissance magnetostratigraphic study was completed, on samples of Kombolgie Formation, from the Deaf Adder Creek and Edith River localities, about 400 kms to the northwest of McArthur River. The Kombolgie Formation is the basal unit of the McArthur Basin succession in this part of the basin.

The stabilities of remanence directions were generally excellent, but the scatter between the sample directions was larger than normally observed. Large scatters had been reported previously from the Hart Dolerite of the Kimberley region, which is of roughly'imilar age. There it was attributed to a very strong dipole field in comparison to the quadripole field. A tentative reversal pattern has been drawn up from these results. Further work is warranted.

1978 Field Program

Following the completion of the McArthur Basin reconnaissance, a further 1200 samples were collected during 1978 to better define the magnetostratigraphic column.

The Kilgour River sections (K1-K12) were sampled at 1 m stratigraphic intervals, through the 1000 m from the Masterton Formation to Emmerugga Dolomite. Thirty test sampdes were collected from various localities in the Kilgour River area to delineate the time of acquisition of the remanence. A 260 m-thick section of Emmerugga Dolomite near Top Crossing (measured section MCB4) was sampled at 3 m intervals, to compare the consistency and correlation of the reversal pattern with that of the Kilgour River sections.

The sampling of the magnetostratigraphic column was extended, on a reconnaissance basis, to include the Wollogorang Formation of the Tawallah Group in the Mallapunyah Dome, and the Amos Formation, Balbirini Dolomite, and Dungaminnie Formation near Balbirini Homestead. A total of 370 samples were collected from these units.

Further sampling of the Kombolgie Formation was also carried out, where 500 samples were collected at 1 m stratigraphic intervals through the sequence, so as to better define the magnetostratigraphic column.

40 samples were collected from the Westmoreland Conglomerate near the southeastern margin of the McArthur Basin, to compare the pole position with that of the stratigraphically equivalent Kombolgie Formation. 35 samples were collected from the isotopically-dated Hobblechain Rhyolite Member and Packsaddle Microgranite, at the top of the Tawallah Group, to help fix the time scale of the polar wander curve which is emerging from the McArthur Basin.

SUBSURFACE STRUCTURAL RESEARCH

The hypothesis that the McArthur Basin contains the central meridional fault-bounded Batten Trough, bounded by shallow shelves on either side, is fundamental to all palaeogeographic analyses and to ore genesis (the McArthur River (H.Y.C.) orebody is adjacent to one of the bounding faults).

The concept of a sudden change in thickness at these faults is speculative, however, because younger cover immediately adjacent to them everywhere obscures the structure of the critical zones on the shelves.

The objective of the 1978 program was to test convenient methods of resolving alternative models of the subsurface structure beneath the reasonably accessible, but unexposed zone, between the Emu Fault and Wearyan River (Figure D4).

MAGNETO-TELLURIC RESEARCH (D. Kerr (Task Leader), J.A. Major, A.G. Spence)

Field Survey

Theoretical modelling of structural profiles along the selected traverse indicated that the magneto-telluric method should be able to differentiate between the alternative models.

Seventeen magneto-telluric sites were occupied between 28 July and 10 October (Figure D4). Electromagnetic responses were recorded continuously for about 2-3 days at each site. Good-quality data were obtained from all sites. A portable computer facility allowed preliminary one-dimensional inversions to be carried out on site, to check the progress of the survey.

The five sites to the east of the Wearyan River are control sites in an area of simple predictable structure. The more closely-spaced stations over the problem area, to the west of the Wearyan River, follow the same line as the gravity survey.

Results

Computer analysis of the data has only just begun. Preliminary one-dimensional modelling of the control sites reveals a well-defined basement of good contrast, with resistivity of about 95 kΩ m.

This is overlain by a fairly consistent high-conductivity layer - 70 m - about 800 m thick. Above this, is a more resistive layer, with resistivities in the range 600-900 Ω m.

A highly conductive overburden, about 10 m thick, has a resistivity of about 2.5 Ω m.

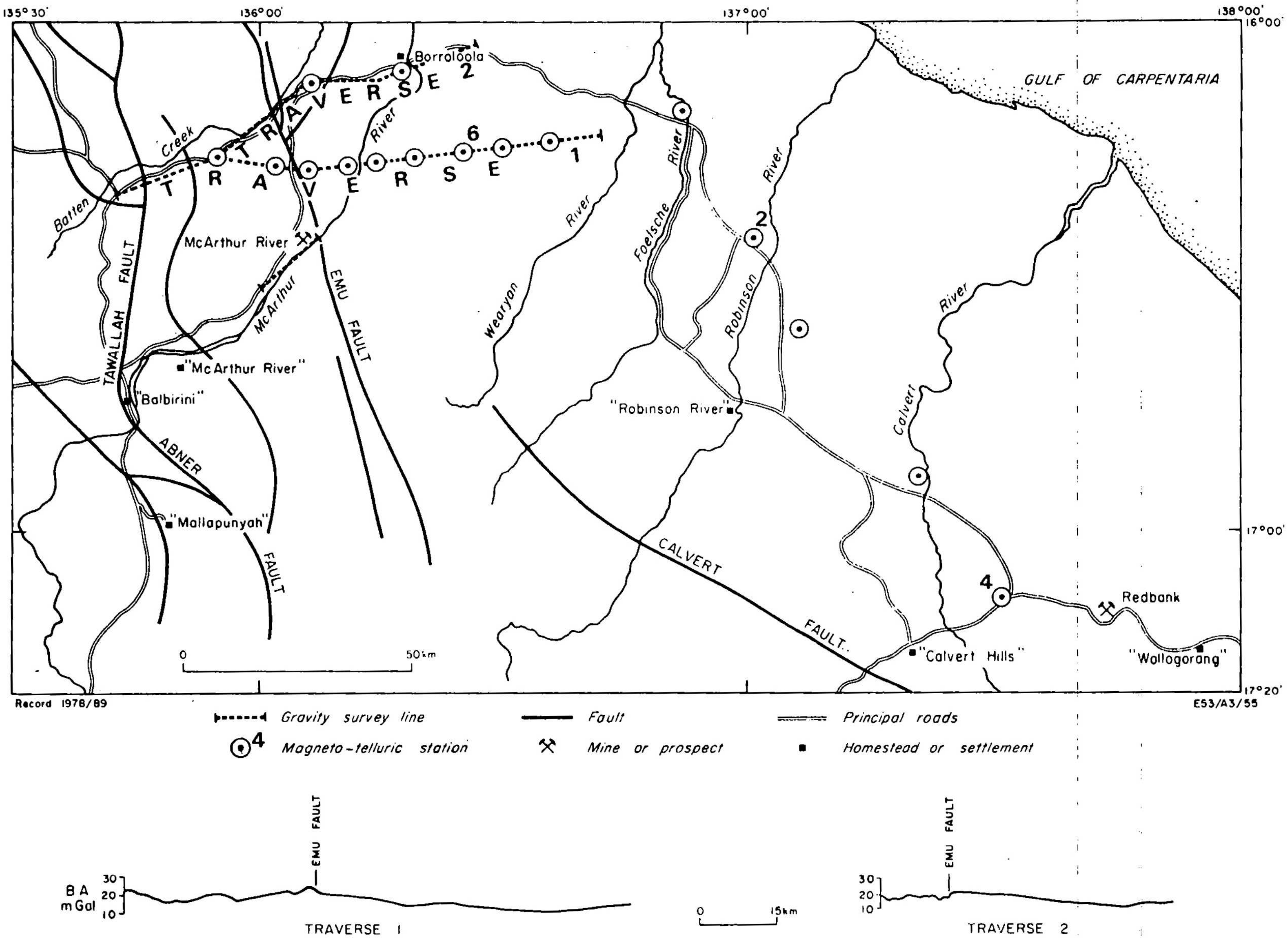


Fig D4 Locality map and preliminary Bouguer anomaly profiles — McArthur Basin magneto-telluric and gravity survey, 1978.

The preliminary calculations indicate a depth to basement of about 2.8 km near Calvert Hills (Site 4), which increases to about 3.5-3.6 km near Robinson River (Site 2). Approaching the Emu Fault a preliminary depth to basement of about 6.7 km has been calculated for site 6, but no data are available from adjoining sites yet, to indicate the nature of the depth change.

These data reveal the presence of well-defined electrical layers, which appear to be capable of simple geological interpretation. The control sites are within reasonable agreement with predicted geological profiles, and the potential of the method for resolving selected structural problems in the McArthur Basin is good.

GRAVITY RESEARCH (W. Anfiloff)

Field Survey

Detailed gravity measurements were made along about 160 km of optically-levelled traverse lines (Figure D4), designed to provide optimum data for assessment of future applications of the method. Station spacing of 0.5 km was used in areas of complex structure or topography, and 1.0 km elsewhere. One short traverse passed over the McArthur River (H.Y.C.) orebody.

Results

Figure D4 shows preliminary Bouguer Anomaly profiles for traverses 1 and 2, from field reduction of the data. More accurate data reduction and interpretation will be carried out with the aid of a computer.

Gravity anomalies in the area are of low amplitude - less than 10 mGal over the whole traverse. This suggests small density contrasts between the various rocks in the area, and the need for detailed and accurate surveys to resolve the required problems.

There is good agreement between the two profiles to the east of the Emu Fault: Bouguer Anomaly values in both profiles decrease slowly eastwards across the platform, away from the fault. The more disturbed profiles to the west of the fault are in agreement with the more complex structure of the Batten Fault Zone.

The profiles are suitable for detailed mathematical modelling and should be of use in resolving problems of subsurface structure. The experience of this survey will be used to plan for and assess the feasibility of future gravity work.

BAAS BECKING GEOBIOLOGICAL RESEARCH LABORATORY

INVESTIGATION OF MODERN SEDIMENTARY ENVIRONMENTS

SEDIMENTOLOGICAL STUDIES IN SPENCER GULF

by

R.V. Burne

STAFF: R.V. Burne, J. Colwell, L. Pain, M. Tratt.

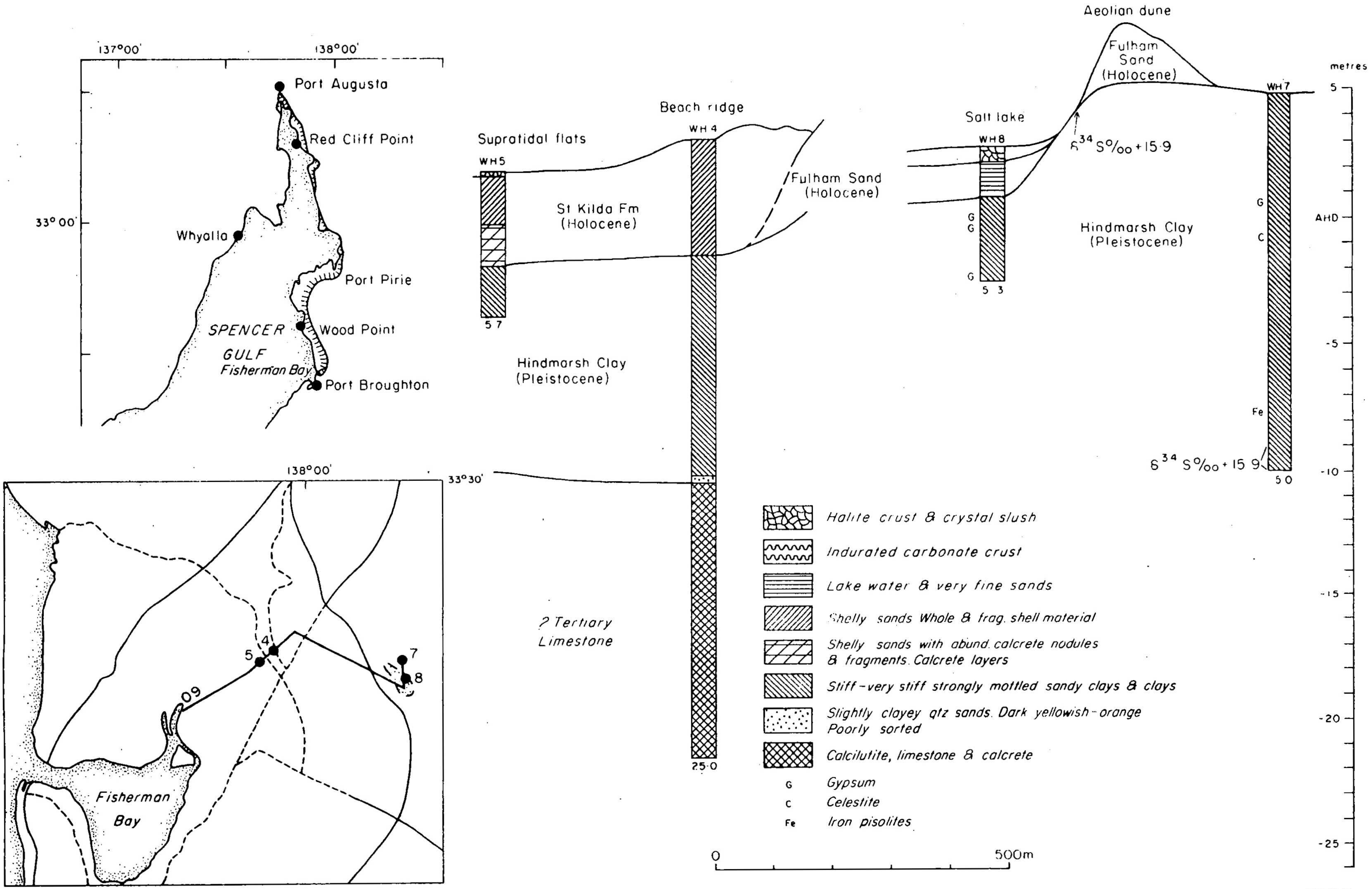
The objectives of this program are to establish the sedimentological framework of the Spencer Gulf environments in which microbiological and mineralogical studies are undertaken and to provide a model for the palaeogeographical interpretation of appropriate orebody host rocks.

In the past year the program has concentrated on the distinction of environments and the description of facies in the vicinity of Fisherman Bay, Mambray Creek, Redcliff, and Wood Point (Fig. B1). Attention has been given to the hydrology and diagenetic processes within these areas and to the reconstruction of the diagenetic history.

During February and March a program of shallow stratigraphic drilling was undertaken in these four areas on the eastern coast of the upper part of Spencer Gulf to elucidate the Holocene depositional history of the areas, to identify the presence and state of any buried concentrations of organic material, to establish the diagenetic processes and products in the areas, and to establish the chemical variation and hydrological distribution of the shallow groundwaters. Thirteen holes ranging in depth from 4.8 to 13.1 m were completed and approximately 150 m of core and 38 groundwater samples recovered.

In each of the areas investigated, a similar sequence was penetrated - Holocene shallow marine, beach ridge and/or aeolian sediments (St. Kilda Formation or Fulham Sand) overlie a thick sequence of Pleistocene. Cross sections through the sequence at Wood Point and Fisherman Bay are shown in Figures B2 and B3. Diagenetic changes within the sediments include the precipitation of gypsum and carbonate. Small amounts of celestite were recorded in one of the holes.

Work currently in progress includes mineralogical examination of the core material and detailed chemical analysis of the groundwaters.



Record 1978/89

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Fig B1 Location and lithological section of boreholes at Fisherman Bay

Sedimentological investigation of the inter-tidal and supra-tidal zones involved detailed examination and sampling of a series of transects designed to traverse the most significant environmental associations of the areas. The Department of Administrative Services has provided a detailed survey of levels along each transect (Fig. B2 and B3) and this critical information coupled with the analysis of the sedimentological data should provide for a precise distinction of environments. In order to understand the zonation of these areas an inundation index is being constructed for the tidally flooded areas of Northern Spencer Gulf by deriving cumulative tide height frequency data from tidal records from Port Pirie and other recording stations in upper Spencer Gulf. Techniques of lacquer peeling suitable for salt water-saturated sediments have been successfully developed and have been used to aid the description of the transect sediments as well as the vibrocores from the 1977 cruise.

As this work progresses a clearer picture of the sedimentary setting of Spencer Gulf is emerging which is failing to support the superficial similarity between this non-tropical semi-arid area of carbonate and sulphate accumulation and the well known Sabkhas of the Trucial Coast of the Arabian Gulf; instead it is providing an interesting alternative model for the interpretation of ancient sequences.

The sediments of the supratidal zone consist of a thin clay layer overlying cryptalgal-laminated carbonates. Although a thin layer of fine-grained gypsum crystals of marine origin does occur at the base of the brown clay at the seaward side of this zone, the thickest accumulation of gypsum is at the highest landward zone of the supratidal pans, around groundwater resurgence gullies. Small ephemeral lakes with discoidal gypsum and even halite accumulations occur locally just shoreward of the supra-tidal zone. These observations seem to indicate that, in Spencer Gulf, the main origin of evaporite minerals may be from the concentration and evaporation of continentally-derived brines, rather than from sea water.

Detailed chemical and sulphur isotope analyses of groundwaters obtained from the drilling and transect studies have been undertaken to attempt to assess the relative influence of marine and continentally-derived brines in the area. (See report by Ferguson and Plumb, p. 236-238).

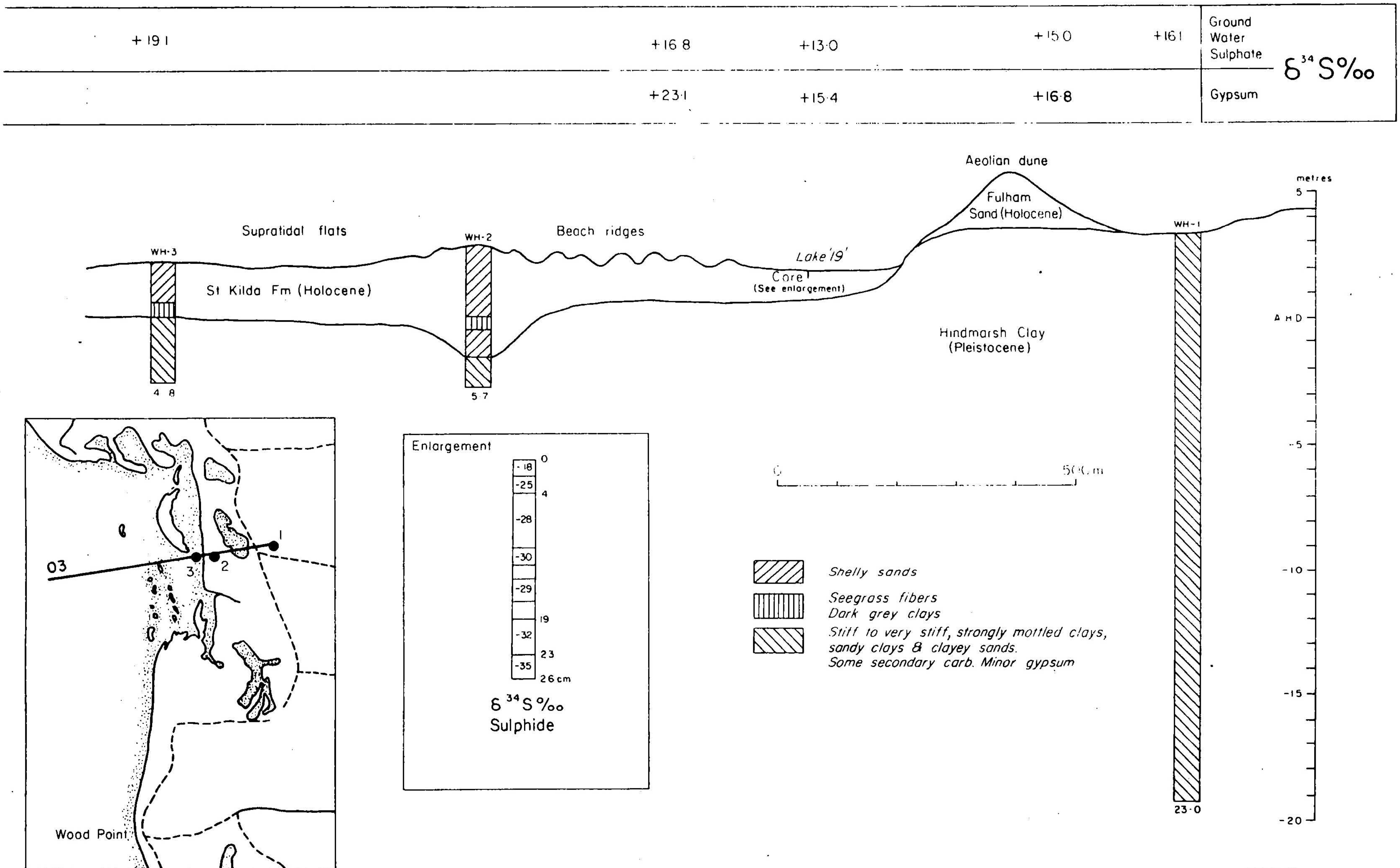

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Fig B2 Geological cross-section and isotopic composition of groundwaters, Wood Point area

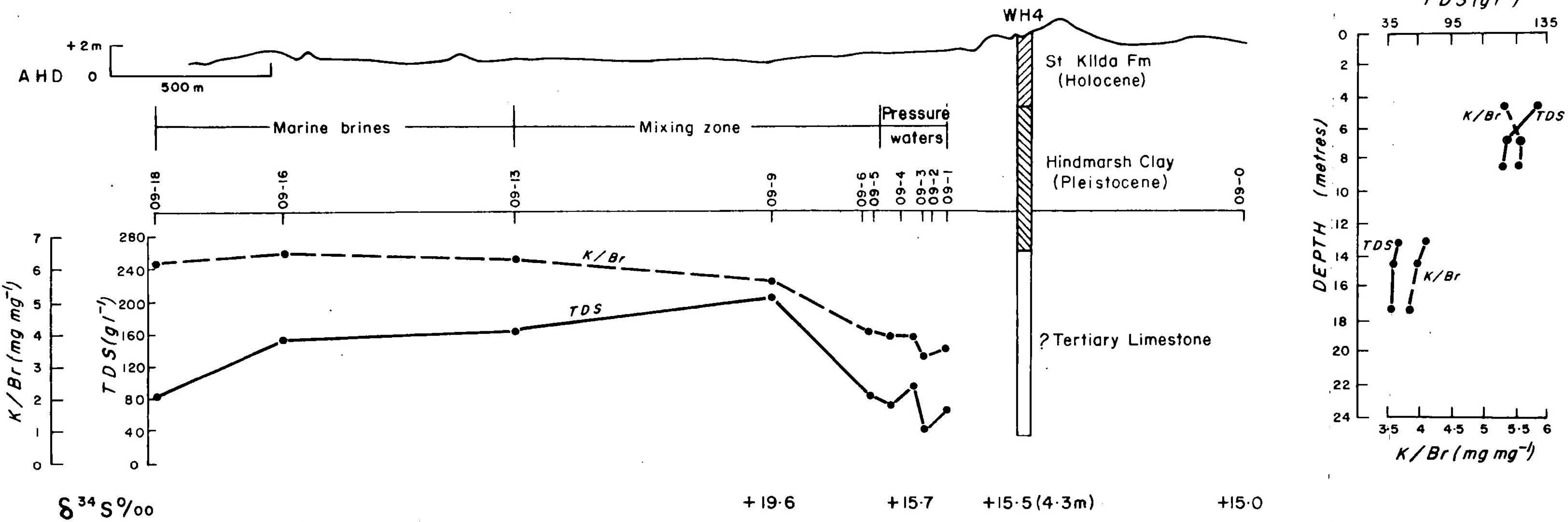

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Fig B3 Geochemical composition of groundwaters at Fisherman Bay

Further evidence of a continental origin for the evaporating brines has come from the discovery of charophyte zygotes in association with gypsum discs in a core from a coastal ephemeral lake. Charophytes have been assumed to inhabit only freshwater environments, but in the last year we have identified a number of occurrences of charophytes in ephemeral salt lakes with irregular salinity variations. We conclude that an association of charophyte oogonia and gypsum characterises evaporites which have formed from brines of either wholly or partially non-marine derivation.

This association has drawn attention to two ancient evaporite sequences which do not seem to be adequately explained by the Persian Gulf evaporite model, but which, as knowledge of the semi-arid Spencer Gulf model accumulates, are demonstrating several parallels with the South Australian Holocene sequence: these are the Lower Purbeckian of Southern England, and the Tertiary evaporites of the Paris Basin.

ORIGINS AND GEOCHEMISTRY OF NEAR-SHORE BRINES OF SPENCER GULF

by

James Ferguson and L.A. Plumb

STAFF: R.V. Burne, J. Colwell, James Ferguson, D. Fitzsimmons, L. Pain, and M. Tratt (BMR); L.A. Plumb (CSIRO).

Intertidal and supratidal areas of Spencer Gulf are sites for a variety of chemical and biological processes which are fundamental to models proposed for the formation of certain types of sedimentary ore. Field evidence indicates that these processes are strongly influenced by the presence of marine or continental brines which, at some locations, have formed iron-rich sediments, deposited carbonate and evaporite minerals and have acted as sources of sulphate for bacterial sulphate reduction.

In the present investigation sulphur isotope and chemical data are being used to investigate the origin of brines from coastal areas at Fisherman Bay, Wood Point and Mambray Creek (Fig. B1), and to interpret sulphur isotope patterns and mineral assemblages in the associated sediments.

A preliminary classification into marine, mixed and continental brines has been made on the basis of $\delta^{34}S$ values of dissolved sulphate, ion ratios (particularly $^{K}/_{Br}$) and changes in chemical composition along a transect across intertidal and supratidal areas. Detailed interpretation of the continental brines is not complete but there are at least two, and possibly up to four, chemically different types. Figure B3 illustrates changes in water chemistry along a transect and down a drillhole at Fisherman Bay, where sea water and two types of continental brine are evident. The distinction between the continental brines is most obvious in analyses of water from drill-hole W.H.4. where the relatively dilute pressure waters associated with the Tertiary limestone contrast sharply in chert salinities and $^{K}/_{Br}$ ratios with the overlying water in the Hindmarsh Clay (Fig. B3). The waters which emerge onto the tidal flats near the base of the sand dune (09-1, Fig. B3) are chemically similar to the pressure waters, and the chemical changes along the transect towards the sea indicate mixing of these waters with brines derived from seawater. This is supported by the rapid change of the $\delta^{34}S$ values of dissolved sulphate towards a ratio characteristic for seawater sulphate.

A contrasting situation occurs at Wood Point (Lake 19, Fig. B2) where the continental input is from groundwater associated with the Hindmarsh Clay. This groundwater introduces dissolved sulphate with an isotope value of $+15^{o}/oo$. Associated gypsum shows a slightly enhanced ^{34}S value ($+16.8^{o}/oo$) which, on the basis of theoretical calculations and experimental results, indicates precipitation in equilibrium with the groundwater sulphate. This relationship can also be seen between groundwater sulphate and gypsum within "Lake 19" but not between gypsum ($\delta^{34}S$ $+23.1^{o}/oo$) and the present associated groundwater sulphate ($\delta^{34}S$ $+16.8^{o}/oo$) in the beach ridges. Such gypsum probably indicates the earlier influence of undiluted sea water at this site. Further seaward, the isotopic composition of groundwater sulphate approaches that of sea water. All the sulphur isotope data can be explained on the basis of a continental brine meeting and mixing with seawater-derived brines. The zone of mixing may change with climatic conditions resulting in "seawater" gypsum in a currently continental regime.

Within "Lake 19" itself sulphides, gypsum and sulphate in solution have been analysed for sulphur isotope abundances. The iron sulphide shows considerable enrichment of, and regular increase in, ^{32}S abundance with depth. This pattern would be consistent with successive episodes of bacterial reduction of a limited sulphate supply which moved upwards under evaporative pumping. There is no real indication of the extent of fractionation since the comparatively uniform $\delta^{34}S$ for porewater sulphate indicates more recent invasion by the current groundwater.

Sulphate in both groundwater and interstitial waters of "Lake 19" has a slightly increased ^{32}S content compared with the sulphate in inflowing groundwater. If incoming brine were not anoxic, it is possible that small amounts of the very light sulphide could be oxidised and contribute sufficient ^{32}S-enriched sulphate to account for the difference. Interstitial water sulphate near the surface appears a little lighter (+12.2^{o}/oo) than at other levels (+13.2^{o}/oo) and a near-surface layer of gypsum (+16.9^{o}/oo) heavier than elsewhere (14.8^{o}/oo). This additional ^{32}S in the topmost porewater may have arisen from some aerial oxidation of the earlier formed light sulphide.

Currently, attempts are being made to define the major chemical reactions influencing the formation and diagenesis of the brines. Data on the marine-derived brines indicate that fresh sea water flooding the tidal flats increases the salt content by three main processes: (1) evaporation, (2) dissolution of salts precipitated in the sediments after previous inundations and (3) mixing with concentrated "residual" brines in the sediments. The seawater brines are generally saturated with respect to gypsum and depletions in their calcium contents indicate that significant precipitation of calcium carbonate and sulphate minerals has occurred.

PRIMARY PRODUCTIVITY IN ALGAL MATS IN SPENCER GULF

by

J. Bauld

STAFF: J. Bauld, C. Manning, M.R. Reed (CSIRO).

The objective of the biological studies on Spencer Gulf is to determine the primary biological factors governing sulphur, metal and carbonate transformations in a modern sedimentary environment.

Since organic carbon supplies the energy requirements for sulphide formation by sulphate-reducing bacteria, particular emphasis is placed on measuring primary productivity (the production of organic carbon by photosynthetic CO_2-fixation) of mat-forming blue-green algae. Primary productivity is determined experimentally by a radioisotopic method whereby CO_2 is supplied as ^{14}C-Na_2CO_3.

A final assessment was made of potential experimental areas during field work in November 1977. Highest priority was assigned to two areas - Mambray Creek and Fisherman Bay. These are high intertidal-supratidal areas where extensive blue-green algal mats grow. Generally the mats consist of a thin (1-2 mm) surface layer of living filamentous blue-green algae overlying a black zone of active sulphate reduction.

The mats are subjected to wide variations in salinity due to evaporation of water remaining in topographic lows as tides recede. A preliminary experiment indicated that the blue-green algae in the mats are unaffected by salinities up to 3 times seawater (ca. $105^{o}/oo$). However, if the salinity is increased from 3 to 4 times seawater, photosynthetic $^{14}CO_2$- fixation is diminished by about 50%.

The effect of DCMU, an inhibitor of oxygenic photosynthesis, on algal mat CO_2-fixation was tested during <u>in situ</u> experiments. Some 10-20% of photosynthetic $^{14}CO_2$-fixation was insensitive to DCMU inhibition. These data suggest that some of the blue-green algae in the mat may utilize H_2S as an alternative electron donor during photosynthesis or, possibly, that there is some activity by photosynthetic bacteria lower in the mat. In either case this process may be a significant H_2S sink, thus competing with metals.

Primary productivity rates of algal mats in the Mambray Creek intertidal area were at least 60 mg C $m^{-2}h^{-1}$ during midsummer. Later experiments indicate that some 25-50% of the total primary productivity would have remained undetected. A rate of supply of organic carbon of 60-120 mgC $m^{-2}h^{-1}$ would be sufficient to support the sulphate reduction rates determined for these mats.

During a brief excursion to Holocene carbonate environments in S.A. and W.A. primary productivity experiments were carried out on selected algal mat types and some components of subtidal stromatolites.

SULPHATE REDUCTION RATES IN ALGAL MAT SEDIMENTS

by

G.W. Skyring, and L.A. Plumb

STAFF: I.A. Johns, L.A. Plumb, M.R. Reed, G.W. Skyring, M. Thomas and P.A. Trudinger (CSIRO).

The rates of bacterial sulphate reduction in selected sediments have been assayed to determine the quantitative relationships between carbon fixation and sulphate reduction and the extent to which such sediments may be representative of those in which large-scale sulphide mineralisation has taken place. The radioactive assay method used was demonstrated to give statistically reliable results.

Spencer Gulf

The patterns of sulphate reduction rates, obtained for samples taken monthly from three stations at Mambray Creek are given in Figure B4. Standard deviations from the means both for sulphate reduction rates and sulphide concentrations (see Fig. B4) were generally around $\pm$20 to 50%. There appears to be little difference in rates obtained for samples from all stations between November and April, except for a possible trend towards decreasing rates in samples from Station 10M over the same period. The significantly higher rates noted in the May and June samples from stations 8M and 10M may have been due to unusual climatic conditions characterized by fresh water floods. The sulphide concentrations in samples from stations 8M and 10M were similar but those in station 4M samples were generally lower (Table 1). Excluding the high winter rates for stations 8M and 10M the average of all sulphate reduction rates was 12 mmol $m^{-2}d^{-1}$ (or 0.38 mg sulphide $m^{-2}d^{-1}$). Including the high rates the average was 28 mmol $m^{-2}d^{-1}$. These rates are high in comparison with those of many other ecosystems and in previous studies we concluded that rates of this order would be sufficient to account for a biogenic origin for a McArthur River-type orebody.

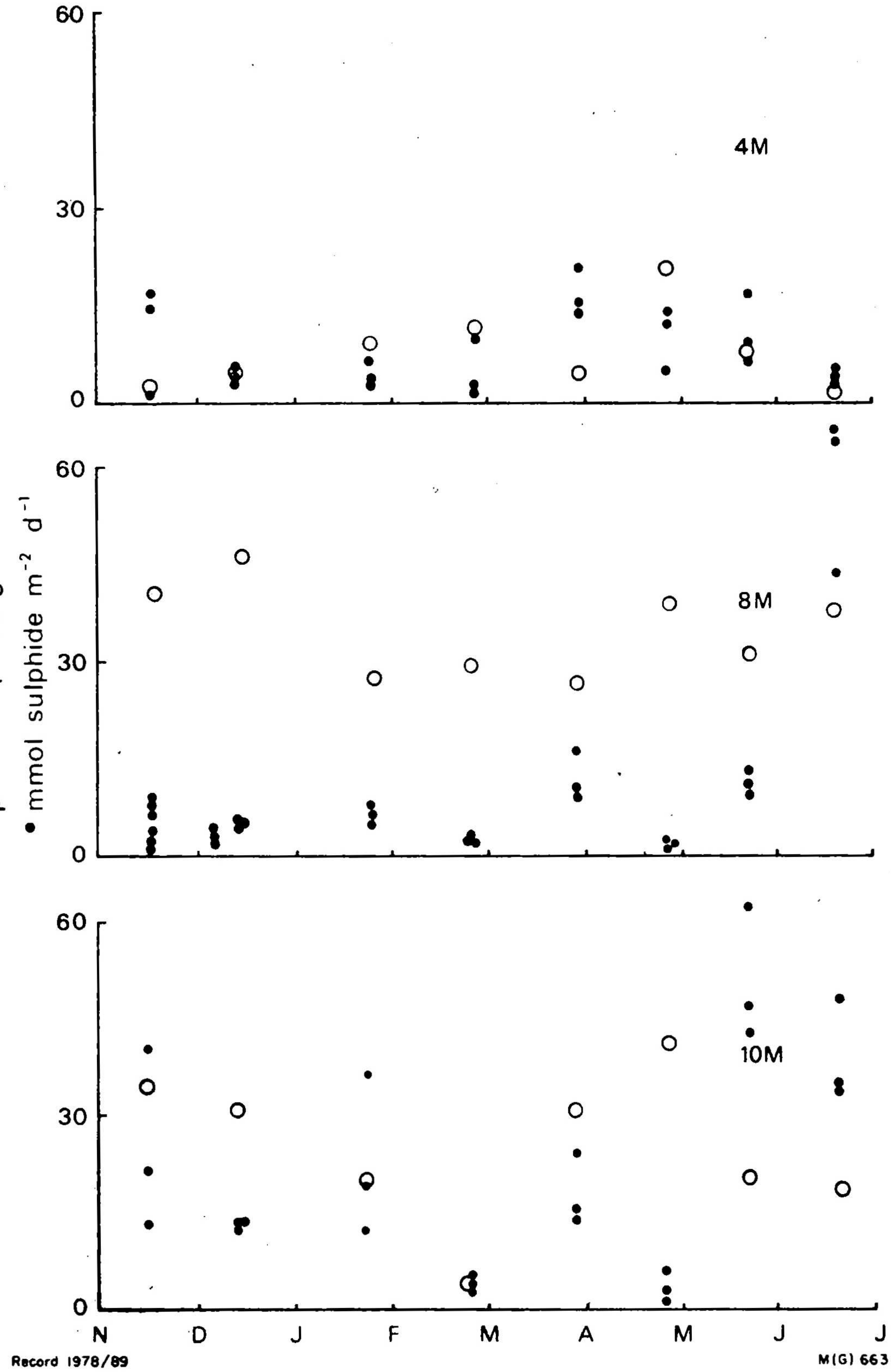

Fig. B4 The sulphate reduction rates (•) and the sulphide content (O, $\bar{x}$ of at least three assays) determined for each of the Mambray Creek Stations at monthly sampling periods.

TABLE B1: Sulphate concentration in pore water

SAMPLING PERIOD	MAMBRAY CREEK STATIONS 4M	8M	10M
	mM SULPHATE IN PORE WATER		
NOV '77	95	139	115
DEC '78	198	143	137
JAN	96	147	154
FEB	128	122	183
MAR	103	182	145
APR	72	107	83
MAY	55	53	115
JUN	47	85	71

This conclusion is subject to a number of qualifications. Firstly it assumes that the sulphide is trapped in the sediment and is eventually transformed to mineral sulphides. Table B2, however, which shows a comparison of the total sulphide measured at monthly intervals in the upper 2 cm of Mambray Creek sediments with the expected increments in sulphide (calculated from average sulphate reduction rates), shows that considerable amounts of sulphide are lost. Whether this loss is due to oxidation or diffusion of hydrogen sulphide from the sediments remains to be determined.

TABLE B2: ISOTOPIC COMPOSITION OF SULPHIDE IN THE UPPER 2CM OF SEDIMENT (MAMBRAY CREEK)

STATION	DATE	SULPHIDE mol. g^{-1} TOTAL	CALCULATED INCREMENT	$\delta^{34}S^{o}/oo$
M4	Nov. 77	26		-17.2
	Jan. 78	25	19	-15.1
	Feb. 78	27	3	-15.9
	Mar. 78	5	10	-14.3
	April. 78	23	12	
	May 78	31	19	
	Jun. 78	1	16	
			79	
M8	Nov. 77	63		-15.7
	Jan. 78	14	21	-14.4
	Feb. 78	29	14	-14.1
	Mar. 78	37	13	-12.7
	Apr. 78	62	7	
	May 78	50	6	
	Jun. 78	49	34	
			95	
M10	Nov. 77	61	-	-16
	Jan. 78	66	56	-16.6
	Feb. 78	12	12	-9.1
	Mar. 78	52	9	-15.0
	Apr. 78	70	9	
	May 78	58	24	
	Jun. 78	21	43	
			153	

Secondly, several results demonstrated that most sulphate reduction activity is confined to the zones of active growth of algal mat:

1. At both Mambray Creek and Fisherman Bay 90% of the sulphate reduction activity was in the upper 1 cm of sediment.

2. At Mambray Creek during March, the rate of sulphate reduction in a sediment covered with actively growing algal mat was 17 mmol $m^{-2}d^{-1}$, compared with 1 mmol $m^{-2}d^{-1}$ for an area of dying algal mat. Moreover, the rate of reduction in algal mat now buried 18-23 cm below the present surface, and devoid of living algae, was only 0.2-3.4 mmol $m^{-2}d^{-1}$.

3. The sulphate reduction rates at Fisherman Bay increased by an order of magnitude during May (compared with December and June) when the algal mat was extensively covered by water, a condition which favours algal growth (Table B3).

TABLE B3: RATES OF SULPHATE REDUCTION IN FISHERMAN BAY SEDIMENTS

DATE	mmol $m^{-2}d^{-1}$
6/12/77	1.9*
28/2/78	1.2
26/5/78	21.0

Shark Bay

During March, Shark Bay, Western Australia, was visited in the company of J. Bauld, R. Burne, M. Jackson, J. Kennard, M. Muir and M. Walter. This environment is characterised by many Sabka-like features and a varied and extensive development of stromatolites. The excursion was led by Dr. P.

Playford of the Geological Survey of Western Australia. One purpose of the visit was to evaluate Shark Bay as a potential environment for future studies by the Laboratory. The visit also provided the opportunity for further integration of the research interests of the Baas Becking and BMR personnel.

TABLE B4: SULPHATE REDUCTION RATES, SULFIDE CONTENTS, AND $\delta^{34}S^{o}/oo$ VALUES FOR SHARK BAY SEDIMENTS

STATION DESCRIPTION	SULPHATE REDUCTION RATES mmol $m^{-2}d^{-1}$	mol SULPHIDE g^{-1} SEDIMENT	$\delta^{34}S^{o}/oo$ POREWATER SULPHATE	$\delta^{34}S^{o}/oo$ ACID LABILE SULPHIDE
1. Organic rich thickly laminated black sediment	19*	88*		-14.5
2. Same as for 1 but apparently more recent	69	56	+27.7	-11.5
3. Same as for 1 but further seawards	14	34	+22.0	-11.9
4. Same as for 1 but different location	29	51		
5. Pustular mat sediment	0	0		
6. Smooth mat sediment	4.6	6	+20.7	-23.2
7. Sandy sediment between columnar stromatolites	4.9	4		

(* is the arithmetical average of at least 3 assays).

Samples from 7 different stations on the intertidal zones of Hamelin Pool were taken for sulphate reduction rate assay. The results are given in Table 4 which also contains stable sulphur isotopic data and a brief description of the kinds of sediments studied. The rates in the organic-rich, thickly laminated sediments were generally very high. It was apparent that the organic matter contained in these sediments was derived from gelatinous material sloughed off from the extensive stand of inter-and subtidal columnar stromatolites. The sloughing of the stromatolites was accentuated by the high tides and rough seas resulting from cyclonic conditions a few days prior to sampling. It is possible that enormous quantities of organic matter dislodged from a large surface area of columnar stromatolites could be transported to deep or shallow basins by wind and tide action. In such organic rich sediments, high rates of sulphate reduction could occur.

ISOTOPIC PATTERNS AND SULPHIDE DISTRIBUTION IN ALGAL MAT SEDIMENTS

by

L.A. Plumb

STAFF: L.A. Plumb, M. Thomas (CSIRO).

Sulphide resulting from bacterial sulphate reduction is considerably enriched in ^{32}S compared to the sulphate from which it arises and the phenomenon has been used extensively in interpretations of isotope data from ancient sediments. This project is designed to establish what isotopic patterns may be expected in sulphide forming in sediments underlying present-day intertidal algal mats.

Sulphur isotope analyses have been done on acid labile sulphides and pore-water sulphates from cores taken at the same times and locations as the material for the determinations of sulphate reduction and carbon dioxide fixation rates. The cores were sectioned horizontally to differentiate the black sulphidic bands which, between samplings, vary quite considerably in position (Fig. B5), possibly due to scouring, rapid sedimentation or oxidation of sulphides. Variations due to sampling appear unlikely since sulphide concentrations calculated to a 5 cm depth all agree closely with results obtained, by a different analytical technique, during sulphate reduction rate determinations.

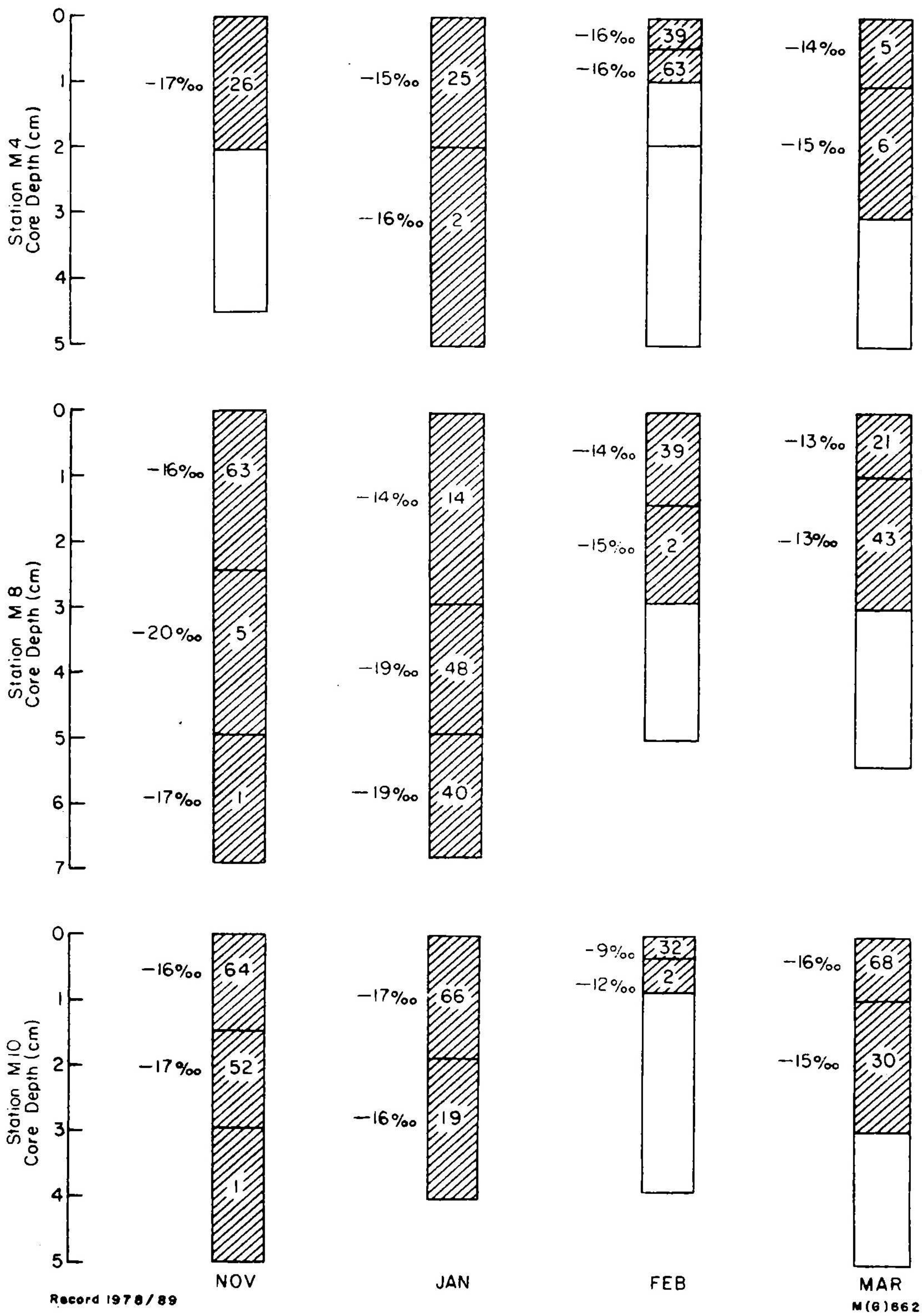

Fig. B5 $\delta^{34}S$ ‰ of sulphide for sectioned cores from Mambray Cr stations. Data on diagrams are µ Mol. sulphide per gram dry weight.

$\delta^{34}S$ values for pore-water sulphate are little different from seawater sulphate (+20.5^{o}/oo) except for one sample from Station 2 at Shark Bay (Table 4) which exhibits particularly high sulphate reduction rates. Sulphide values at Mambray Creek and Shark Bay range between -9^{o}/oo and -23^{o}/oo (Tables B2 and B4, Fig. B5), with most values falling about -16^{o}/oo. This is an average fractionation of -35.5^{o}/oo relative to seawater sulphate, which is in the range of the higher fractionations obtained in experimental systems and which is usually associated with a low rate of sulphate reduction per cell. This may indicate that the high overall rates of sulphate reduction in Mambray Creek sediments(see p.240) are the result of high populations of bacteria with relatively slow metabolic activity.

THE POTENTIAL OF INTERTIDAL ALGAL MATS TO CONCENTRATE IRON FROM SEA WATER

by

G.W. Skyring

STAFF: I.A. Johns, M.R. Reed, G.W. Skyring (CSIRO)

It has already been mentioned(p.242) that considerable quantities of sulphide, produced by sulphate reduction, are lost from algal mat sediment. An important question arises, therefore, as to what factors govern the fixation of sulphides. Since iron is one of the most common sulphide fixatives in the natural environment we are examining the ability of algal mats to concentrate iron from seawater and their potential role in sulphide immobilization. Scanning electron microscopic (SEM) techniques are being employed in conjunction with energy dispersive X-ray analysis.

Progress may be summarised as follows:

1. X-ray dispersion spot analyses of areas of high iron concentration in the laminated mat structure indicate that iron appears to be predominantly in the form of iron potassium silicates which also contain sulphur. Many of these areas were not represented by discrete particles but appeared to be associated with interstitial zones as was previously noticed.

2. Small quantities of iron also appear to be associated with filaments of algae.

3. Although pyrite does not appear to be a major component of the various sulphur compounds in these sediments, framboidal structures, which are composed of iron and sulphur only, have been observed.

4. Granules in which only sulphur can be detected are frequently found on the surface of the algal mat. The origin of this sulphur has not yet been elucidated although it is suspected that it has arisen from the oxidation of H_2S escaping from the mat-sediment system.

To facilitate SEM-Xray studies on the distribution of elements (particularly S, Fe, Si and Ca) in algal mat sediments, a system for the simultaneous mapping of any two elements (or combinations of elements) in the Periodic Table above sodium has been developed. Figures B6A and B6B are examples of this technique. We have found the technique very useful for studying these structurally complex sediments.

STUDIES OF HEAVY METALS

by

James Ferguson

STAFF: B. Bubela, C.R. Manning, L. Plumb, C. Robison, M. Thomas (CSIRO); James Ferguson, D. Fitzsimmons (BMR).

Solution, transportation, and precipitation of base metals are vital components of most models of low temperature base metal sulphide mineralisation. Investigations at Spencer Gulf are partly aimed at establishing the nature of these processes operating within a natural environment. However, because the concentration of metals is normally low in such environments, special emphasis is being placed on areas around the BHAS smelting complex at Port Pirie, where over the years there has been some escape of metals and deposition in the Gulf waters.

During this year, research has been focussed on two aspects of metal contribution to Spencer Gulf by First Creek, which serves as a drain for aqueous effluent from the smelter. Firstly, attempts have been made to define the reactions involved as the present-day metal-bearing effluent interacts with the marine environment. Secondly, changes undergone by metals since they were deposited in the offshore sediments have been determined. Most of the Pb, Zn and Cd in these sediments was deposited when emissions from the smelter were considerably different from those being introduced today.

A

Fig.B6A Distribution of Si (dot) and S (bar) in a freeze dried, embedded and polished section of algal mat from Mambray Creek S.A. Field of view, 1.5 x 1.4mm.

B

Fig.B6B Distribution of Ca (dot) and Cu (bar) in a cupriferous carbonate vein from Kapunda S.A. Polished section, field of view 8 x 7.5 mm.

To establish whether the effluent creek discharge had significantly increased trace metal concentrations offshore a limited survey of dissolved metals in near-surface seawater of Spencer Gulf was undertaken. The results showed that Cu and Cd concentrations and, with the exception of the area near Port Pirie, Pb and Zn concentrations were close to average for nearshore ocean water. Near Port Pirie, concentrations of Pb and Zn are about 10 times higher than elsewhere and within this area the highest concentrations occur nearest the point of discharge of the effluent creek. This suggests they are related to the discharge of aqueous effluent, rather than the deposition and dissolution of particulate aerosols from the smelter.

To determine if significant changes in the speciation of the metals occurred after their discharge into the Gulf, a series of water samples was collected starting at the effluent creek and proceeding in the direction of the tidal flow towards unaffected areas. Preliminary results indicate that 90% of Pb, Zn and Cd in the effluent creek itself and at least 50% of Pb and 60% of Zn in the tidal channel leading to Spencer Gulf is readily adsorbed by an imidodiacetic acid-type resin. This "weakly complexed" metal should be readily available for participation in chemical and/or biological processes in the offshore marine environment.

Investigations of metals in the offshore sediments has involved a study of three vibrocores, two from areas remote from the smelter and one from Pb-, Zn- and Cd- enriched sediments offshore from the effluent creek. Data on metal concentrations in the sediments and interstitial waters have been supported by a detailed geochemical and mineralogical investigation of the core. Particular emphasis has been given to defining the influence of bacterial sulphate reduction on metal concentrations.

The upper sediments of all three cores are subtidal and the main components are calcium and magnesium carbonates. The core from near the smelter contains considerable amounts of seagrass which supported a zone of active bacterial sulphate reduction. This had led to high concentrations of dissolved sulphide (55 ppm) in some of the pore waters and corresponding increases in alkalinity and decreases in dissolved sulphate. One of the "remote" cores also has abundant seagrass but it appears relatively fresh and bacterial sulphate reduction was not well established. The third core shows no evidence of bacterial sulphate reduction. Sediments in the cores older than those of the subtidal zone vary widely in composition and include white, grey-yellow and red clays.

Concentrations of Pb up to 600 ppm, Zn up to 1000 ppm and Cd up to 100 ppm occur in the top 50 cm of the core from near the Smelters. The concentrations decrease, and the Pb/Zn ratios increase with depth in a manner which suggests that both airborne particles and metals from the effluent creek are contributing to the area. The form in which the metals reach the sediments has not yet been determined. "Background" metal concentrations in carbonate sediments are near 10 to 20 ppm for Zn, 10 ppm for Cu and less than 5 and 1 ppm for Pb and Cd, respectively. In red continental clays of the metal-enriched core values of Cu and Zn are 3 to 4 times higher than in the overlying carbonate sediments. Cu and Zn concentrations do not correlate and they are probably associated with different components of the clay.

Trace metal concentrations in interstitial waters of the cores show sharply contrasting patterns for Pb, Cu and Cd, as compared to Zn. Unlike a number of other sedimentary environments Pb, Cu and Cd concentrations are not significantly greater than those in the overlying seawater. This is so for the metal-enriched sediments where the metal concentrations which could be mobilized are at least an order of magnitude above those of normal sediments. It appears likely that the "inertness" of the metals in the sediments, rather than the solubility of the metals in the interstitial waters controls the metal concentrations in solution. Zn, in contrast, is present in higher than seawater concentrations throughout most of the cores and is extremely high (392 ppb) in pore waters associated with the metal-rich surface sediments from the polluted area. Also, the Zn concentrations are at a minimum in the zone of highest dissolved sulphide. This suggests that Zn is readily available from the sediments and its concentration in the interstitial waters is determined by the solubility of ZnS, and in low-sulphide waters, Zn hydroxide species. The possibility that at least part of the Zn is in solution in the form of organic complexes will be assessed when testing of an experimental technique for the UV-destruction of organic matter is complete. Sulphide generated in sediments of the core from the polluted area is being fixed mainly as iron sulphides. The proportion of acid-labile (probably iron monosulphides) sulphide decreases and that of Zn-reducible (probably pyrite) sulphide increases with increasing depth. This probably reflects the diagenetic conversion of initially formed iron sulphides to pyrite. Only a small proportion of the total Fe in the sediments is sulphidised, despite the presence of high dissolved sulphide in the pore waters. This indicates that only a very small proportion of the Fe, possibly only that present as surface coatings on grains, is available for reaction. Acid-labile sulphide in the topmost sediments of the metal enriched core is an order of magnitude higher than those below. Further, this sulphide has a $\delta^{34}S$ value of $24.9^{o}/oo$ which contrasts sharply with the values near zero which are characteristic of ore refined at the smelters. It seems likely, therefore that most of the metals deposited in the sediments have been converted to sulphides by bacterially produced hydrogen sulphide.

ORE GENESIS INVESTIGATIONS

INVESTIGATIONS OF COPPER MINERALISATION, ADELAIDE GEOSYNCLINE AND STUART SHELF, SOUTH AUSTRALIA

by

I.B. Lambert, J. Knutson and T.H. Donnelly

STAFF: T.H. Donnelly (CSIRO), J. Knutson (BMR) and I.B. Lambert (CSIRO)

The main objective of these investigations is to compare the isotopic, geochemical, mineralogical and petrographic features of mineralised and unmineralised strata from several areas through the Adelaide geosyncline and Stuart Shelf in an attempt to define metallogenetic processes and exploration guides. Our studies in the Mount Gunson, Lake Dutton and Myall Creek areas on the Stuart Shelf, and at Kapunda in the Adelaide Geosyncline, are well-advanced, and preliminary suites of samples have been collected for proposed studies in the Willouran Ranges and at Mount Painter.

Mount Gunson area (Pacminex). Mineralisation in this area occurs in two main forms. The most important is in the Cattle Grid deposit, which occurs in the uppermost Pandurra Formation. Here, chalcocite (djurleite), digenite, bornite, and chalcopyrite mineralisation, with some associated pyrite, sphalerite, galena, and carrolite, infills fractures and vugs in strongly brecciated quartzite. This epigenetic mineralization appears to have formed in a palaeo-weathering zone on the Pandurra Formation.

The second form of mineralisation occurs in the overlying Tapley Hill Formation which shows varying degrees of enrichment in base metals throughout the Stuart Shelf and the Adelaide Geosyncline. Pyrite framboids are abundant and tend to be concentrated in silty lenses of the finely laminated dolomitic siltstones so characteristic of the Tapley Hill Formation. In some instances these framboids are partly or totally replaced by chalcopyrite, bornite and chalcocite/digenite. Chalcopyrite, bornite and chalcocite also occur as small angular fragments suggesting the possibility that some of the Cu-sulphides have a detrital origin. In other instances, local remobilization has resulted in coarse-grained sulphides, recrystallized carbonate and in some places secondary quartz infilling solution channels and/or desiccation cracks. The main non-sulphide minerals in the Tapley Hill Formation at Mount Gunson, as in the other areas studied on the Shelf, are dolomite, quartz, scricite, chlorite and feldspars and there are no obvious alteration minerals associated with the mineralisation. Uncommonly, sulphide-bearing fragments from the Tapley Hill and Pandurra Formations occur in the over-lying Whyalla Sandstone, implying that mineralisation pre-dated the deposition of the fragments in Whyalla Sandstone.

The widespread occurrence of finely laminated rocks, in the Tapley Hill Formation in which layers of siltstone, silty dolomite and dolomite are commonly less than 0.5 mm thick, indicates a rather special depositional environment. The abundance of sliver-shaped detrital grains suggests the possibility that this unit incorporated glacial flour which was introduced in fluvial systems as the climate warmed up after the Sturtian glaciation.

In addition to anomolously high Cu, Pb and Zn contents, the Tapley Hill Formation in the Mount Gunson area is commonly enriched relative to average shale in Ag, As, Bi, Co, Cd, Hg, K, Mn and Ti, but not in U and V; it is depleted in Ca and Na, and Fe varies from anomalously high to lower than normal shale values. The base metals are more anomalous in the dolomitic shales than in the dolomites. Organic C contents of most samples are normal for shales, and significantly less than in black shales. There is generally only slight enrichment of Pb and Zn with Cu, and it is rare for contents of these elements to exceed 0.15% and 0.4% respectively.

Sulphur isotope ratios for the Cattle Grid Mine are similar to those in other Cu deposits in the Pandurra Quartzite around Mount Gunson. The $\delta^{34}S$ values range from $-4^{o}/oo$ - $23^{o}/oo$ and are indicative of biological sulphate reduction in each deposit. However, they do not distinguish between:-

(i) in situ reduction, involving considerable replenishment of sulphate and

(ii) introduction of biogenic sulphide minerals from other units by fluids which flowed into the Pandurra Quartzite.

In contrast, the $\delta^{34}S$ values for sulphides from the Tapley Hill Formation are in the range from about $-1^{o}/oo$ to $+43^{o}/oo$ with an average value about $+20^{o}/oo$. These are unusually positive values, but similar results have been found in the Tapley Hill Formation at other localities. These are indicative of bacterial reduction of sulphate that was enriched in ^{34}S relative to seawater, in a restricted basin(s) with little or no influx of seawater.

Lake Dutton area (Pacminex). In this general area, the Tapley Hill Formation is thicker, with a lower overall dolomite content than at Mount Gunson. The Zn and Pb contents are variable and locally anomalous, but no significant Cu anomalies were encountered in our studies. Compared with the Mount Gunson samples, those from the Lake Dutton area have higher contents of S (pyrite), organic C, Na and Si, lower (but still commonly anomalous) contents of Ag, As, Bi, Hg and Mn, and no significant Co anomalies. Details of trends in chemical data are presently being assessed. $\delta^{34}S$ values for disseminated sulphide minerals, mainly pyritic, are again positive and highly variable.

Myall Creek (Australian Selection). Anomalous concentrations of Cu, Pb and Zn occur as disseminated grains and veinlets in dolomitic shales, silty and sandy beds near the base of the Tapley Hill Formation and, to a minor extent, in carbonate veins in underlying brecciated and altered volcanics.

The Tapley Hill Formation at Myall Creek again contains highly angular to sliver-shaped quartz grains, but it has a lower proportion of highly dolomitic rocks than at Mount Gunson. The sulphides occur as disseminated grains, blebs and veinlets. Fine-grained chalcopyrite in the dolomitic shales is commonly seen to replace or nucleate on framboidal pyrite and fine-grained chalcocite grains are typically angular or irregular. Coarse sulphide blebs are most common in silty and sandy beds; these characteristically comprise chalcopyrite, bornite and chalcocite and some contain relic pyrite framboids. There does not appear to be a significant detrital sulphide component.

The Tapley Hill Formation at Myall Creek is again enriched in Ag, As, Co and Hg, but compared with Mount Gunson, Mn is less enriched and Bi is not anomalous. Furthermore, unlike Mount Gunson, high Pb and Zn values persist above the basal cupriferous zone. Details of the geochemical relationships are being assessed.

The $\delta^{34}S$ values for disseminated sulphides of Myall Creek fall in the range +9 to +45% (except for two values of $-20^{o}/oo$ and $-15^{o}/oo$). The values for discordant sulphides fall within this range ($+12^{o}/oo$ to $+38^{o}/oo$, except for a single value of -12%) implying derivation from the sedimentary sulphides. These unusually positive $\delta^{34}S$ values are similar to those in the Tapley Hill dolosiltstones at Mount Gunson, Lake Dutton and Kapunda.

<u>Kapunda</u> (Utah Joint Venture). In the Adelaide Geosyncline, the Tapley Hill Formation is considerably thicker than on the Stuart Shelf, and it has been recrystallized under slightly higher grades of metamorphism (low to middle greenschist facies). At Kapunda the sequence comprises massive to well-bedded, dark grey to buff coloured siltstones. The main minerals in both cupriferous and non-mineralized lithologies are quartz, dolomite, muscovite and chlorite, with variable albite and potash feldspar and, in some cases, biotite. Dolomite rarely exceeds 30%, which is much lower than on the Stuart Shelf. Sulphide minerals are characteristically minor components along laminae and in segregations with quartz and carbonate; the overall order of abundance is pyrrhotite > pyrite > chalcopyrite, with the main concentrations of chalcocpyrite being in buff siltstones. Numerous discordant, coarse-

grained, carbonate-quartz-sulphide veins occur in the buff dolositltstone with disseminated chalcopyrite. In many cases, bedding laminations in the silt-stones are disturbed near the veins, which commonly have protruding margins.

Chemical trends at Kapunda differ from those found in the other areas studied in not exhibiting significant enrichments of Ag, As, Bi, Co, Hg, Mn, Pb or Zn; there are occassional high U values in mineralized silt-stones at Kapunda, but S and C are generally lower than in the other areas. There is no obvious geochemical alteration halo around the mineralization. Statistical treatment of the chemical results is to be undertaken.

The sulphides in quartz-carbonate veins at Kapunda have been found to have a wide range of positive $\delta^{34}S$ values ($+5^{o}/oo$ to $+32^{o}/oo$) which are within the range for the sulphides in the sedimentary rocks at Kapunda ($0^{o}/oo$ to $+45^{o}/oo$), and the other Tapley Hill sequences studied. These results strongly imply derivation of the vein sulphides from the "sedimentary" sulphides. Carbon and oxygen isotopic data show wide ranges of compositions for carbonate from veins ($\delta^{13}C = -2^{o}/oo$ to $-19^{o}/oo$; $\delta^{18}O = +4^{o}/oo$ to $+19^{o}/oo$) and sedimentary rocks ($\delta^{13}C = +5^{o}/oo$ to $-25^{o}/oo$; $\delta^{18}O = -3^{o}/oo$ to $+24^{o}/oo$). Further data are being gathered to assess the significance of the differences between the isotopic patterns for these two forms of carbonate.

ISOTOPE STUDIES IN THE PINE CREEK GEOSYNCLINE, N.T.

by

T.H. Donnelly

STAFF: T.H. Donnelly, I.B. Lambert (CSIRO); G. Ewers, John Ferguson, and D. Tucker (BMR).

Base metal sulphide deposits in the Rum Jungle area

This isotope study of the Mount Bonney and Brown's Cu-Pb-Zn deposits and the Woodcutters Pb-Zn deposit, all of which occur in the same stratigraphic position at the base of the Golden Dyke Formation, has been largely completed and reported in previous annual summaries. Some further work is being carried out on sulphides within amphibolites in the Mount Bonnie area to try to determine sources of the sulphur.

Investigation of magnetic anomalies (residual magnetism) over the Pine Creek Geosyncline

A selected drill core is being studied to try to determine the nature of the magnetism involved. To carry out this investigation mineralogical studies, quantitative elemental analysis and stable isotope studies are being carried out.

Stable isotope investigation of minerals associated with uranium mineralisation in the Alligator Rivers Belt

Minerals associated with three uranium deposits Jabiluka, Ranger 1 and Koongarra have been isotopically examined. Work is nearly completed and the data are presently being assessed.

STABLE ISOTOPE STUDIES ON NORTH POLE BARITE AND BIG STUBBY BARITIC SULPHIDE DEPOSITS, PILBARA, WESTERN AUSTRALIA

by

I.B. Lambert & T.H. Donnelly

STAFF: T.H. Donnelly, I.B. Lambert in collaboration with the University of Western Australia and mining companies.

This study follows the same theme as our previous investigations on Archaean volcano-sedimentary sequences in Western Australia, Rhodesia and Greenland (Geological Branch Summary of Activities, 1976 and 1977). The 3.4 b.y. old North Pole barite deposits and the similarly ancient Big Stubby baritic sulphide prospect are important because of the rarity of Archaean sulphate deposits. Specifically, our studies have been designed to assess the source of the sulphate, and to place constraints on the geobiochemical evolution of the early Earth.

The work has been written up and submitted for publication. Results suggest the following general scenario for the early Archaean:

(i) juvenile, sulphurous exhalations (H_2S, HS^- SO_4^{2-}) were being added to the hydrosphere and atmosphere;

(ii) there was local oxidation of reduced sulphur by microbes (or photolysis), but oxygen was not necessarily a stable component of the atmosphere;

(iii) bedded sulphate deposits formed in shallow-water, evaporitic environments (North Pole);

(iv) relatively small, baritic sulphide deposits precipitated directly as a result of volcano-exhalative activity (Big Stubby);

(v) sulphate-free, exhalative sulphide mineralisation formed in deeper water and/or lower fO_2 environments; and

(vi) bacterial SO_4^{2-} reduction was absent, or not of widespread significance.

EASTERN CREEK Pb-Ba PROSPECT, McARTHUR BASIN, N.T.

by

T.H. Donnelly and M.D. Muir

STAFF: T.H. Donnelly (CSIRO), M. Muir (BMR)

The Eastern Creek Pb-Ba Prospect occurs in the Kookaburra Creek Formation at Eastern Creek in the Mount Young 1:250 000 sheet area (SD 53/15). The mineralisation is conformable with bedding, as well as occurring in cross-cutting bodies. The Kookaburra Creek Formation is stratigraphically equivalent to the Balbirini Dolomite of the McArthur Basin, and the prospect occurs in the middle of the formation. On sedimentological grounds, the environment of deposition is very shallow water, and possibly non-marine.

The purpose of this study is to assess ore genesis through stable isotopic, mineralogical and geochemical studies.

Drill core from 3 drill holes of the Eastern Creek area have now been sampled. Thin sections have been cut for petrological, and possible fluid inclusion, studies. Other small slabs have been cut for scanning electron microscope studies. Samples have been drilled out (micro drill) for stable isotope studies of various sulphides, carbonates and barite. The powders from these samples are at present being examined for their purity by X.R.D. before isotope studies commence.

LABORATORY STUDIES

SIMULATED SEDIMENTARY SYSTEMS

by

B. Bubela

STAFF: J. Bauld, B. Bubela, I. Johns, C.R. Manning, L.A. Plumb, C.R. Robison, G.W. Skyring (CSIRO); James Ferguson, D. Fitzsimmons (BMR).

EVAPORATIVE SEDIMENTARY ENVIRONMENT

A laboratory system based on a number of reservoirs of total capacities approximately 3000 litres and with hydraulic and electronic accessories capable of simulating a variety of parameters present in evaporative sedimentary environments has been developed. The system is being used in the following investigations:

i) an evaluation of biological and physico-chemical parameters influencing biological production of H_2S.

ii) the role of carbonates, during their formation and diagenesis in metal accumulation and deposition.

iii) rates of biological processes, including carbon fixation, in the living algal mat at the water - sediment interface.

iv) mineralogy of heavy metals precipitated as sulphides and/or carbonates from seawater.

v) changes in the composition of organic material in the sediments. Formation of organo-metallic complexes and their effect on metal accumulation, transport and deposition.

vi) changes in porosities and permeabilities of sediments and their effect on the mobility of aqueous and gaseous phases.

vii) formation of evaporites on the surface of the sediments during low water level and their role in metal accumulation.

A detailed description of this system is presented in: "A system for the simulation of sedimentary environments" by Bubela, B., Johns, I.A., and Ferguson, James. A patent application -PD5154/78 (Signal Processing Module) has been taken out for a pH multi-probe monitor associated with the system.

The system was filled in May 1978 with carbonate material, organic matter, and seawater in distinct layers to simulate certain processes occurring in marine evaporative environments.

The temperature of surface waters is being kept at 22 $\pm$ 1^{o}C which has resulted in a stable temperature of 15^{o}C in the sediments in the middle of the tank. The apparatus is illuminated in a 12hr-on, 12hr-off cycle. The following changes have already been noted.

Porosity

The porosity of the sediments decreased on average by 12%, the porosity range being 35-52%. A similar range was observed with samples collected at Stations 4, 8 and 10 at Mambray Creek in Spencer Gulf.

Permeability

The permeability of the sediments decreased from 90 mD to 10 mD. Such a decrease of permeability is probably due to a number of factors:

a) settling of the sediments.
b) gelatinous nature of the organic material in the sediments.
c) establishment of an algal mat at the sediment-water interface
d) precipitation of mineral material in interstitial spaces.

The permeabilities of sediments collected at Stations 4, 8 and 19 at Mambray Creek were 16, 14 and 7 mD respectively.

Algal mat

A continuous algal mat developed at the sediment surface from fragments of algal material collected at Spencer Gulf. The mat consisted of a variety of algae with purple photosynthetic bacteria colonising the lower surface. After 6 weeks the mat was 1 mm thick and visually similar to that found at Spencer Gulf. It had a wet volume of 1000 ml m^{-2}, a dry weight of 224 g m^{-2} and an average water content of 73%.

The permeability of the wet membrane was < 0.1 mD, making the upper surface practically impermeable to gases or liquids at hydrostatic pressures less than 300 kPa. When air-dried at 20°C, the mat stayed flexible and no increase in permeability occurred on rewetting. If dried at a higher temperature or left out of water for more than 2 weeks, it became distorted, brittle and its permeability increased irregularly due to the formation of cracks.

The algal mat acts as a semipermeable membrane and is capable of selective accumulation of Zn and Cu from an aqueous solution.

The biological components and the mineral incrustation on the top of the mat are being investigated.

Mineralogy

No changes in the mineralogy of the carbonates have been observed. Black inorganic material developed through the sediments. The material was unstable in air, and H_2S was released on its acidification. It gave no characteristic X-ray diffraction pattern.

Acid-labile sulphide was found in all the layers of the tank starting in the sediments immediately under the algal mat, with a maximum concentration of 16 ppm in the aragonite layer immediately above the organic layers. The organic material, magnesium calcite and the sand contained 3.5, 2.9 and 4.0 ppm of acid-labile sulphide respectively.

Aqueous phase

The aqueous phase (natural seawater) has undergone a number of significant changes. The oxygen content of the water decreased to zero, from an original value of 6 ppm, at all levels except the surface water, where it stayed practically unchanged. The Eh values of the interstitial water fell to between ~-300 mV and ~-400 mV. The Eh of the surface water was ~+200 mV, that immediately under the algal mat ~ 300 mV.

The pH values of the seawater (originally 8.2) dropped to 7.0 in the sand, 8.0 in the magnesium calcite, 7.0 in the organic layer, and 6.5 in the aragonite layer. The changes in pH may be due to the biologically produced CO_2.

The calcium and magnesium contents increased in the surface waters from 380 and 1184 ppm to 1030 and 8250 ppm respectively. The concentrations in the interstitial waters increased to 1080 ppm and 3250 ppm respectively. The change in the Mg and Ca concentrations resulted in a change in the Mg/Ca ratio from ~ 5:1 to ~ 13:1 in the surface water, while the ratio in the intertidal waters did not change significantly. The increase of Ca and Mg in the waters may be due to the solubilisation of the carbonates by biologically-produced CO_2. The highest increases of Ca and Mg in the surface water was probably due to surface evaporation resulting in an increase of dissolved solids from 3.5 to 9.9%.

Elemental sulphur formed on the surface of the surface waters during the first 2 weeks of the operation. It amounted to ~ 10 g m^{-2} of the surface. Isotopic investigation is underway to determine if the sulphur was derived from sulphide produced by bacterial reduction of sulphate.

Free H_2S

The highest H_2S concentration (95 ppm) was detected in the interstitial water of the aragonite layer. The concentrations of organic material, magnesium calcite and sand were < 1, 1.2 and 2.8 ppm respectively.

Gases

Gas production took place in the sediments. Some of the gases were trapped in the sediments, but most were trapped under the algal mat in volumes of several hundreds of millilitres. The composition of the gases is being investigated. Preliminary results indicate CH_4 and CO_2 as the major components.

Biological processes

Preliminary results of the measurements of the rates of biological reduction of sulphates indicate the zone of maximum activity to be in the aragonite, just above the organic material. Such results are in agreement with the observations on the distribution of acid-labile and free H_2S. Experimental work to measure the biological rates of the algal population are in progress.

Conclusions

The simulated system developed a number of characteristics comparable with the natural situation at Spencer Gulf, (e.g. permeability, porosity, temperature, salinity, pH, Eh).

Biological activity resulted in the formation not only of hydrogen sulphide, CO_2 and CH_4 but in the formation of algal mat which is practically impermeable both to water and gases. A formation of such an impermeable barrier has to be taken into consideration in formulating processes involving transport of solutes and oxygen to upper sediments.

Projected Work

The present investigation, besides monitoring the processes in the tank, is concentrated on establishing the lateral permeability of the sediments and its significance on the movements of solutes. The role of the algal mat in diffusion processes as a possible selective membrane is being investigated.

INVESTIGATION OF AIRBORNE PARTICLES CONTAINING HEAVY METALS

To investigate processes involving heavy metal particles originating from smelters at Port Pirie after their deposition on the top of the water column (Spencer Gulf), an apparatus was built, permitting a simulation of some aspects of such an environment.

Particles collected by the production line trapping system (baghouse) are predominantly sulphides of Pb and Zn, in a great variety of sizes. Due to their predominantly hydrophobic surfaces, and possibly to electrostatic charges, such particles associate firmly with the surface of large particles, forming large agglomerates. Samples collected in the stocks are much smaller, the majority being about 0.25 μm in diameter. Samples collected several miles from their source are approximately the same size (0.25 μm), but poor in sulphur. Their detailed chemistry and mineralogy is not known at this stage.

Results obtained so far indicate that the particles, because of their different chemical compositions, have different surface tension characteristics. After their deposition, those with hydrophobic surfaces agglomerate into larger units and sink rapidly, through the water. Particles with less hydrophobic properties do not agglomerate readily and may stay in the water column for a considerably longer time. As a result of this process the population of the particles varies qualitatively and quantatively through the length of the column. The separation is further influenced by the ionic strength, surface activity and temperature of the aqueous phase.

THE ROLE OF MICROBIOLOGY IN ENHANCED OIL RECOVERY

by

B. Bubela

STAFF: B. Bubela (CSIRO)

A study on the status quo of microbiological methods in exploration techniques, enchanced oil recoveries, and oil shale treatment has been completed.

Information collected indicates that at the present time techniques related to the release of residual oil from natural reservoir may significantly profit by introduction of microbiological methods. As the reports available are poorly documented and most of the work has been done on an empirical basis, a considerable amount of work has to be done. A detailed assessment of the problem has been presented in a report by B. Bubela - Role of geomicro-biology in enhanced recovery of oil.

Study of the published literature reveals that there is a number of conflicting views on microbiological degradation of hydrocarbons. This is probably due to the great variety of techniques and environments affecting such processes; and the report includes an evaluation of the situation.

A number of contacts have been made with institutions and individuals involved in relevant investigations. The involvement of microbiology in the enhanced recovery of oil was summarised in a paper presented at the 1978 Annual Meeting of APEA and published in the APEA Journal.

PUBLICATIONS AND RECORDS

PUBLICATIONS AND RECORDS

In this section of the report publications, Open File Records, and Professional Opinions (the latter two categories are regarded as unpublished) prepared in the Geological Branch are listed. The lists include those prepared in the Branch during the year and those prepared in earlier years and issued during the period under review. The period covered is November 1977 to October 1978. The categories of listing are given below, together with the number of papers or maps in each category (corresponding figures for 1977 are shown in brackets).

Bulletins	:	Published 15(4) or in press 7(14)
	:	With editors 17(15)
Reports	:	Published 3(2) or in press 3(4)
	:	With editors 1(2)
Mineral Resources Reports	:	Published 1(0) or in press 1(0)
BMR Journal of Australian	:	Published 33(31) or in press 6(7)
Geology and Geophysics	:	With editor 8(6)
Outside Publications	:	Published 53(66) or in press 51(32)
	:	Submitted and accepted 20(23), or in preparation 13(4) (for BMR authors 'in preparation' means that the paper is with editors)

Maps. Maps are geological maps unless otherwise stated.

1:250 000 scale Maps

Colour edition, with explanatory notes (both map and notes are at least at the stage indicated)

	:	Published 24(19) or in press 13(13)
	:	With editors 6(18)
Preliminary edition	:	Published 7(8) or in press 2(1)
(no notes)	:	Being drawn 11

1:100 000 scale Maps		
Colour edition	:	Published 2 or in press 2(1)
	:	With editors 6(1)
Geochemical maps	:	Published 5
Preliminary edition	:	Published 8(8) or in press 1(1)
	:	Being drawn 18
Special Maps	:	With editors 6(2; 6 published in 1977)
	:	Preliminary edition published 4(3) or in press 0
	:	Preliminary edition being drawn 2
Records	:	Issued 48(33)
	:	With editors 13(9)
	:	In preparation (being edited within the Geological Branch) 15(23)
Professional Opinions	:	Issued 16

Numbers against authors' names 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.
6 Dr D.F. Sangster, Geological Survey of Canada, worked in Geological Branch from May 1977 to May 1978 under an exchange arrangement.

Year of publication or issue is not shown unless it is known to be other than 1978.

BULLETINS

PUBLISHED OR IN PRESS*

166	EXON, N.F.	Geology of the Surat Basin in Queensland.
*167	SENIOR, B.R. MOND, A. HARRISON, P.L.	Geology of the Eromanga Basin.
169	SHERATON, J.W. [1]LABONNE, B.	Petrology and geochemistry of acid igneous rocks of northeast Queensland.
170	[1]COOK, P.J. [1]MAYO, W.	Sedimentology and Holocene history of a tropical estuary (Broad Sound, Queensland).
171	[5]POJETA, J. GILBERT-TOMLINSON, J. SHERGOLD, J.H.	Cambrian and Ordovician rostroconch molluscs of northern Australia.
*172	[1]OPIK, A.A.	Middle Cambrian Agnostacea.
174	[5]POJETA, J. Jr. GILBERT-TOMLINSON, J.	Australian Ordovician pelecypod molluscs.
177	[1]HUGHES, R.J.	The geology and mineral occurrences of Bathurst Island, Melville Island and Cobourg Peninsula, Northern Territory.
178	[5]REINSON, G.E.	Hydrology and sediments of a temperate estuary - Mallacoota Inlet, Victoria.

*182	[1]COOK, P.J. [1]MAYO, W.	Geochemistry of a tropical estuary (Broad Sound, Queensland).
192	The Crespin Volume:	Essays in Honour of Irene Crespin.
	BELFORD, D.J.	The genus Triplasia (Foraminifer-ida) from the Miocene of Papua New Guinea.
	DICKINS, J.M.	Relationship of Mourlonia and Ptychomphalina, Upper Palaeozoic Gastropoda.
	DRUCE, E.C.	Correlation of the Cambrian/ Ordovician boundary in Australia.
	KEMP, E.M.	Microfossils of fungal origin from Tertiary sediments on the Ninety-east Ridge, Indian Ocean.
	SHAFIK, S.	Paleocene and Eocene nannofossils from the Kings Park Formation, Perth Basin, Western Australia.
	Also papers by 10 non BMR authors.	
193	DERRICK, G.M. [2]WILSON, I.H. [1]HILL, R.M. GLIKSON, A.Y. MITCHELL, J.E.	Geology of the Mary Kathleen 1:100 000 Sheet area, northwest Queensland.
194	HOHNEN, P.D.	Geology of New Ireland, Papua New Guinea.

*195	DAVIES, P.J.	Marine geology of the Continental Shelf of southeast Australia.
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1977/57	[1]GOLDSMITH, R.C.M. WILSON, E.G.	Stromlo-Higgins Bulk Supply Main, ACT: geological investigations, 1975, and review since construction, 1977.
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Geol. 78.002	PURCELL, D.C.	Notes on Glenloch Interchange drill-hole No. 1.
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Geol. 78.004	WILSON, E.G.	Notes on Environmental Impact Statement: Nabarlek Uranium Project, Arnhem Land, NT.
Geol. 78.005	WILSON, E.G.	Comments on the Jabiluka Project Draft Environmental Impact Statement.
Geol. 78.007	HOHNEN, P.D.	Slope stability investigation Glenloch Interchange.
Geol. 78.008	McCOLL, D.H.	Inventory and Valuation of the J. & B. Thorn Mineral Collection.
Geol. 78.009	CARTER, E.K. TIMONEY, E.G. ERSKINE, J.C. WILSON, E.G. HALDANE, A.D.	Comments on environmental review and management program for proposed metallurgical research plant at Kalgoorlie, WA.
Geol. 78.013	HOHNEN, P.D.	Groundwater resources available for irrigation at ANU campus.

Geol. 78.014	CARTER, E.K. HALDANE, A.D. WILSON, E.G. HABERMEHL, M. GOURLAY, A.J.	Comments on environmental review and management program for Wagerup Alumina Project, WA.
Geol. 78.015	HENDERSON, G.A.M.	Notes on the geology of Black Mountain Reserve.
Geol. 78.016	WALTER, M.R.	Report on an examination of sedimentary rocks in the Mount Isa district.
Geol. 78.017	CARTER, E.K. HALDANE, A.D. TIMONEY, E. HABERMEHL, M.A.	Comments on Western Mining Corporation Yeelirrie uranium project, WA, draft environmental impact statement and environmental review and management programme.
Geol. 78.018	HOHNEN, P.D.	Water supply for Cuppacumbalong Homestead.
Geol. 78.020	HALDANE, A.D. GOURLAY, A.J. WILSON, E.G.	Comments on Reynolds Australia Alumina Ltd environmental review and management program for Worsley Alumina Project.
Geol. 78.022	WALTER, M.R.	Fossil microbiota of the Madley Diapir, Officer Basin.
Geol. 78.023	BELFORD, D.J.	Samples from northwest of Kundiawa and from Woodlark Island, Papua New Guinea.