REPORT 208

Geological Branch Summary of Activities 1977

Department of National Development

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT 208

GEOLOGICAL BRANCH
SUMMARY OF ACTIVITIES
1977

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1978

DEPARTMENT OF NATIONAL DEVELOPMENT

Minister: The Hon. K.E. Newman, M.P.
Secretary: A.J. Woods

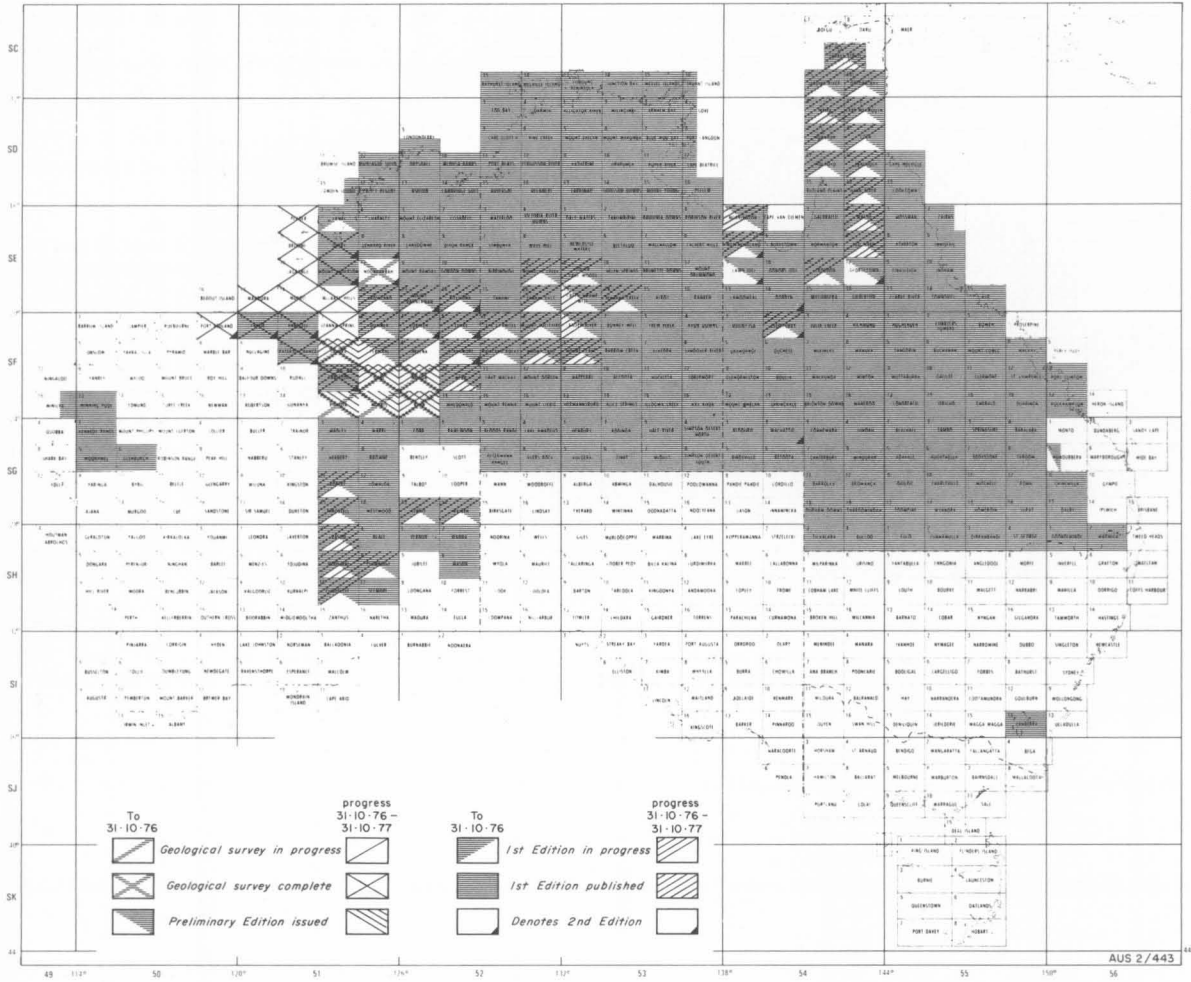
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Director: L.C. Noakes, O.B.E.
Assistant Director, Geological Branch: J.N. Casey

Published for the Bureau of Mineral Resources, Geology and Geophysics by the Australian Government Publishing Service

Manuscript Received: January, 1978
Issued: May, 1978

Printed by Watson Ferguson and Co., Brisbane



ANTARCTICA

1:250 000 SERIES MAPS
PRODUCED TO 31·10·77

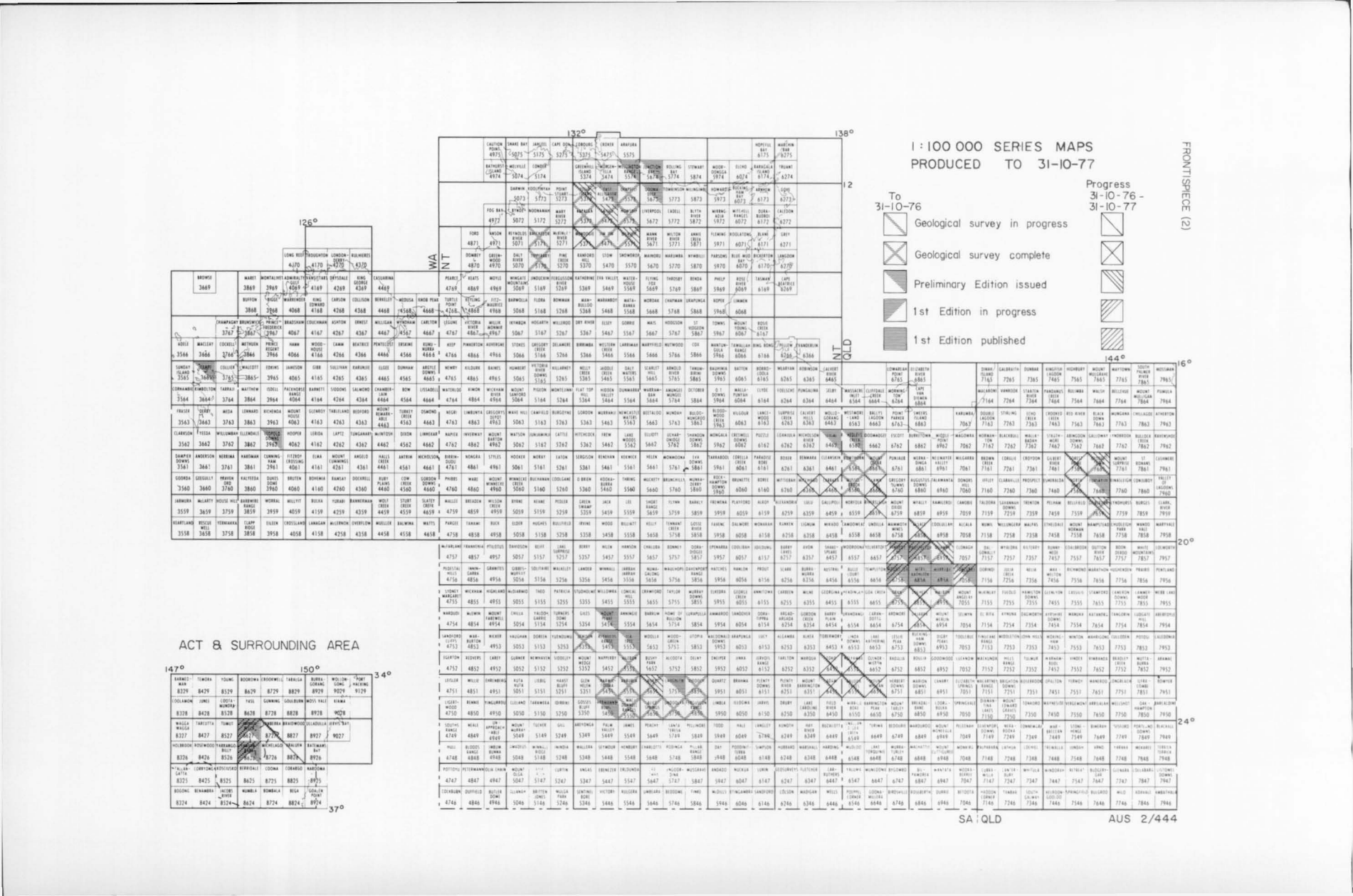
FIELD WORK IN PROGRESS

TO 31·10·77
AKER PEAKS
CAPE BORLEY
CHURCH MOUNTAIN
DISMAL MOUNTAINS
HANSEN MOUNTAINS
McLEOD NUNATAKS
MOUNT CODRINGTON
MOUNT RIISER–LARSEN
NYE MOUNTAINS
PROCLAMATION ISLAND
RAYNER PEAK
SANDERCOCK NUNATAKS
SCULLIN MONOLITH
SIMPSON PEAK
TANGE PROMONTORY

PRELIMINARY EDITION ISSUED

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

FRONTISPIECE (1)


1 : 100 000 SERIES MAPS
PRODUCED TO 31-10-77
To 31-10-76
Progress 31-10-76 - 31-10-77
Geological survey in progress
Geological survey complete
Preliminary Edition issued
1st Edition in progress
1st Edition published
FRONTISPIECE (2)
ACT & SURROUNDING AREA
126°
132°
138°
144°
147°
150°
34°
37°
12
16°
20°
24°
WA
NT
QLD
SA
AUS 2/444

CONTENTS

GENERAL SUMMARY

SEDIMENTARY SECTION

GEOLOGICAL SERVICES SECTION

FIGURES

Page

TABLES

GENERAL SUMMARY

SEDIMENTARY SECTION

by

G.E. Wilford

Field research in, and synthesis and analysis of information from, sedimentary basins occupied one-third of the staff throughout the year. Reporting on the Carpentaria and Karumba Basins was completed in the form of a Bulletin with accompanying 1:1 million geological maps, now with the editors, and papers on land surfaces and late Cainozoic units. The project was started in 1969 in co-operation with the Geological Survey of Queensland. Syntheses of the geology of the Wiso (NT) and Officer (WA) Basins were well advanced at the end of the year.

Field investigations of the poorly known parts of the Canning Basin bordering the northwest shelf were completed in co-operation with the Geological Survey of Western Australia. Work was concentrated on the Jurassic and Early Cretaceous units, and substantial advances were made in their interpretation and in assessing their distribution and relationships.

A reinterpretation of geophysical information from the Ngalia Basin revealed the presence of potentially petroleum-bearing Lower Palaeozoic rocks in the western part where Precambrian rocks had been thought to predominate. Additional sedimentary units, including a second Adelaidean tillite, were mapped during a brief field visit.

BMR activities in the southern Georgina Basin included seismic and airborne magnetic surveys (reported elsewhere) in addition to the Section's field and laboratory studies, and field studies and stratigraphic drilling by the Geological Survey of Queensland. The studies are designed to assist the search for petroleum, stratabound mineral deposits, and phosphate. A helicopter was used to investigate Adelaidean to Early Cambrian sequences resting on granitic basement along the faulted southwestern edge of the basin. Structures mapped include thrusts which pass laterally into normal faults and monoclines. Evidence of possible mineralisation in carbonate units was found. Detailed investigations of the Lower Palaeozoic units confirms the shallow water, commonly evaporitic origin of many of them. Abundant fossil fish collected from the Devonian units will permit their correlation with other parts of Australia.

The multi-disciplinary study of the McArthur Basin, NT, began in mid-year with the field study of the Carpentarian McArthur Group. Twenty-three detailed stratigraphic sections were measured. Preliminary interpretations of the sedimentary structures show that many of the units accumulated in very shallow seas or lakes.

Field research leading to the revision 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. During 1977 reporting on the Tantangara and Brindabella 1:100 000 Sheet areas was completed, fieldwork on the Canberra 1:100 000 Sheet area continued, and that on the Araluen 1:100 000 Sheet commenced. The remaining areas have been mapped by the Geological Survey of New South Wales. A feature of the work in the Tantangara and Brindabella Sheet areas has been the use of whole-rock geochemistry to characterise and distinguish the many Silurian acid volcanic rocks and intrusions.

Studies of the Cainozoic of continental Australia included the palynology of lignites from the Ti Tree and Hale River areas of the Northern Territory and the sampling of ferruginous parts of weathering profiles in Queensland and the Northern Territory for remanent magnetism dating studies. Work in 1976 in the Eromanga Basin showed the major periods of deep weathering to have occurred in Maastrichtian/Eocene and Late Oligocene/Miocene times.

The mathematical model of the Great Artesian Basin was further developed during the year and successfully applied to predict the results of various exploitation schemes. Its documentation continued.

The photogeology and remote sensing group continued to assist with he interpretation of colour airphotos for the Georgina, Pine Creek Geosyncline, Duchess, and Mount Isa-Cloncurry Projects and follow-up field investigations were made in the Georgina Basin and Duchess area. Evaluation studies were made of multiband photography, Landsat imagery, and Skylab photography.

Staff participated in three research cruises on board the Federal Republic of Germany's RV Valdivia, two of which were off northwestern Australia and the third in the Sulu Sea, southern Philippines. Sea bed samples recovered from 30 localities during the second cruise included volcanic rocks of probable Triassic and Jurassic age, fossiliferous Jurassic, Cretaceous, and Cainozoic sedimentary rocks, and ferro-manganese crusts and nodules.

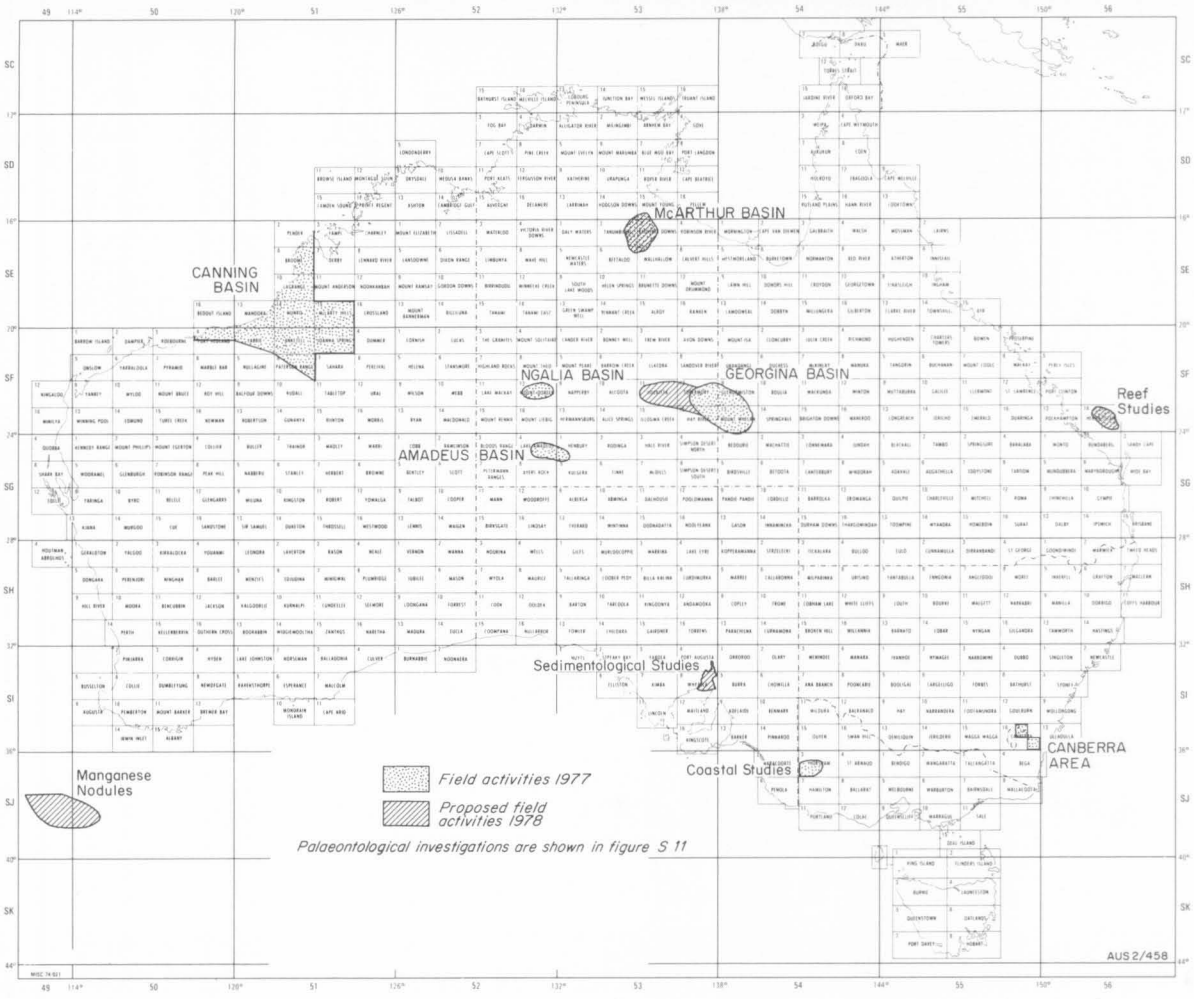


FIG.S1 Sedimentary Section field activities

Reporting on the earlier reconnaissance investigations of the continental shelf of southeastern Australia was well advanced at the end of the year. The results, in two Bulletins, will describe the morphology, structure, distribution, composition, and geochemistry of the superficial sediments underlying the shelf.

Further dredging for manganese nodules off southern Western Australia was undertaken in July-August, providing additional information on this extensive field.

Geophysical and diving techniques were used in a continuation of studies to determine the pre-Holocene unconformity surface in the southern Great Barrier Reef area.

The Palaeontological Group continued with the substantial task of describing, curating, and expanding the national fossil collection in addition to providing support for field-orientated research projects in the Canning, Georgina, and McArthur Basins and the Lachlan Fold Belt. Palaeontological work was carried out for the Papua New Guinea Geological Survey and in support of a foreign aid project in Irian Jaya. The Group's systematic studies included Precambrian microfossils and stromatolites, Early Palaeozoic trilobites and brachiopods, Late Palaeozoic fish, conodonts, molluscs, ostracods, and spores, Mesozoic molluscs, spores, and pollen, and Cainozoic mammals, floras, foraminifera, and nannofossils.

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 1977 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 field work, and ore genesis studies in sedimentary basins.

The idea behind the Spencer Gulf studies is that an investigation of the relation between sedimentary facies, microbiological processes, and the precipitation and mobilisation of metals, should aid ore genesis studies of

stratabound base metal mineralisation. Spencer Gulf was selected as an area with carbonate sedimentation, moderately high salinities, and one in which there could have been some introduction of base metals through industrial pollution on the eastern shores. In order to undertake these studies Dr J. Bauld, a microbial ecologist, and Dr R.V. Burne, a sedimentologist have been added to the research team. In addition, Dr Skyring spent a year in the United States investigating sulphate reduction in salt marshes of Georgia, and Dr Trudinger and Miss Chambers visited a number of overseas laboratories engaged in investigations of modern environments.

During 1977, sedimentological, microbiological, and geochemical studies were commenced in the northern part of the Gulf and in adjacent intertidal and supratidal environments of the northeastern shoreline. The area has been visited on a number of occasions, one of which included a joint sampling cruise with Drs J.R. Hails and V. Gostin of Adelaide University.

The Gulf investigations are still at an early stage and few results are available as yet. Sufficient has been accomplished to enable construction of a broad sedimentological framework to which the other studies can be eventually tied, but a great deal remains to be done to characterise the sedimentary facies and generate useful sedimentary models.

The microbiological program has commenced and is partly aimed at investigating the role of organic carbon as a primary source of energy in microbiological processes, including those which result in the production of hydrogen sulphide; a variety of environments have been examined and sampled. Other microbiological studies commenced are providing information on sulphur biochemistry by investigations of sulphate, sulphide, and isotopic distributions in various environments.

Geochemical studies during the year have concentrated on identifying those areas of the Gulf in which there may be a sufficient concentration of metals to undertake future research. Early indications are that suitable sites may be found adjacent to the smelters.

The modern environment studies have been supported by research, undertaken in the laboratory, in which the number of variables can be considerably reduced. In particular, much effort has been devoted to the construction of large electronically monitored tanks which will be used to simulate relatively simple sedimentary systems involving unconsolidated sediment, organic matter, and metals. At the same time, research has continued

into the relation between carbonate mineralogy and organic matter, particular attention being given to the significance of molecular size within the organic matter. Studies of sulphur isotope fractionation have also continued.

Ore genesis studies during the year have involved investigations of massive Cu-Pb-Zn deposits in felsic volcanic sequences of southeastern NSW, Cu mineralisation at Redbank, NT, and Cu mineralisation in the Adelaide Geosyncline and on the Stuart Shelf, SA. The studies of the NSW deposits have concerned the delineation of alteration aureoles. Results indicate that the aureoles around deposits at Captains Flat and at Orange are similar to that around the Woodlawn deposit, which was described in the 1976 Summary of Activities (BMR Report 194).

Results of the investigations of Cu mineralisation in breccia pipes at Redbank, NT, point to the involvement of magmatic fluids both in the formation of the pipes and in the mineralisation. There also appears to have been extensive deposition of carbonate and sulphide minerals from brines of connate and mixed connate-magmatic origin.

Studies of mineralisation in the Adelaide Geosyncline and on the Stuart Shelf have not progressed sufficiently as yet to provide any significant results.

GEOLOGICAL SERVICES SECTION

by

E.K. Carter

On 28 February the Geological Drawing Office, having been amalgamated with the two other Drawing Offices, was transferred to Operations Branch; its activities for the whole year are reported in that Branch's Summary of Activities. In the latter part of the year it was necessary to suspend the maintenance of technical files and the mineral index to meet higher-priority commitments.

The work of the Engineering Geology Subsection continued at a similar level to 1976. The two major engineering projects in the Canberra region, for which geological services were provided, were the Googong Dam (now virtually complete) and its appurtenant works, and the Ginninderra

Sewer Tunnel, about one-third complete. In October 1977 a start was made on geological investigations for the siting and design of a new bridge over the Murrumbidgee River near Tharwa. Geological services during construction were provided for two other sewerage projects. Beyond the ACT region the Subsection was involved in the design investigation for cable tunnels below several main streets of the centre of Melbourne, for Telecom Australia, and in preliminary studies of three water supply schemes in Indonesia.

A wide variety of problem-solving investigations related to the development and maintenance of Canberra was undertaken and resource assessments were continued. A major study was that of the origin, distribution, and control of a substantial body of hydrocarbons which had polluted groundwater in the Bunda Street, City, area. Ignition of fumes had caused the death of a workman in the Centre Cinema; evidence was given at the coronial enquiry. Six other groundwater or drainage problem-solving studies were done or continued, and observations of groundwater at Lake George were maintained.

A new edition of the Canberra 1:50 000 Sheet, including Tuggeranong and Gungahlin districts, was compiled and further progress was made with the 1:10 000 scale engineering geology maps of the Canberra urban area.

Use of the Museum by the public, including school groups, continued to increase; several excursions were conducted for school groups. During the year roughly 1500 visitors were received. In addition displays were mounted at three interstate exhibitions, and parts of the Latz Collection, acquired in 1976, were displayed in Parliament House. A highly successful collecting expedition to Browns Deposit, Rum Jungle, involving the reopening of the deposit, resulted in the acquisition of many thousands of dollars worth of prime specimens of cerussite, malachite, and pyromorphite. A fine donation of historical specimens from central Australia was received on behalf of the Commonwealth Government, from Mr and Mrs D. Boerner. Other excellent display specimens were obtained by exchange and purchase.

Mineralogical research was carried out on specimens from Browns Deposit and Cobar, and identification and other services were provided for a wide range of organisations and individuals, including BMR officers. Cataloguing of named collections and new acquisitions continued through the year.

The Transit Room despatched, and carried out the necessary paper work for, 8190 samples for thin sectioning, chemical analysis, or other determinations; 377 samples for thin sectioning were held at the end of the period.

The Map Editing and Compilation Group edited 23 maps; one was in progress at the period's end. A draft of the revised Standard Geological Symbols booklet was distributed to State Surveys and BMR officers for final comment in May and will be issued next year. Most of the map compilation effort was devoted to 1:10 million scale maps for the BMR Earth Science Atlas. Work was done on eight maps, several of which are being fair-drawn. Some of the maps will also be used for other publications. Contributions were made to several other map projects, and notes for several of the maps, including the 1:2.5 million geological maps of Australia and of the Northern Territory published in 1976, are in progress.

Indexing of stratigraphic names and definitions, and the related services to Australian geologists, were maintained during the year: 775 names and about 100 definitions were recorded.

Two mineral reports - on antimony and molybdenum - were completed and passed to the editors and the arsenic report was updated for a Record.

METALLIFEROUS SECTION

by

K.R. Walker

All field research objectives were attained, and work is continuing on about 25 major projects including specialist laboratory studies. Good progress was made with report writing and map production, and 150 manuscripts of various types were completed; many of these were submitted and accepted for publication outside BMR.

Geological field projects in the Metalliferous Section are multidisciplinary involving, as required, airborne and ground geophysics, geochemistry, geochronology, palaeomagnetism, petrology, and isotope geology. The major field effort continues to be the geological re-investigation of the Precambrian of northwestern Queensland. Parties were active in the Duchess, Alsace, and Lawn Hill areas, and, with helicopters to aid traverse work, they completed field investigations in Dajarra, Duchess, Alsace, Riversleigh, Lawn Hill, and parts of Carrara and Mitchiebo 1:100 000 Sheet areas. Interestingly, by the end of the field season, differences in generally accepted stratigraphic relations for the region began to emerge from the Duchess Party field work, which affect the allocation of various units to the Tewinga,

Malbon, or Mary Kathleen Groups. It is hoped that work in the coming year will resolve these differences, and for next year a major effort to finalise the field work is planned to complete the field investigations of outstanding 1:100 000 Sheet areas, hopefully clearing the way for completing report writing and map production by 1982.

Field work for the Georgetown project was completed with the mapping of Forest Home and North Head 1:100 000 Sheet areas, enabling 1978 to be devoted to the finalisation of maps and writing up. Results of 1977 field work have been significant in reaching a proper understanding of the Precambrian Etheridge Group. In addition, isotopic dating techniques combined with detailed structural studies and assessments of metamorphic grade have been used to date five tectonic events in the Georgetown Inlier. Progress with geochemical survey work in the area is at an advanced stage and the first of a new series of computer plotted geochemical maps is now ready for the printer.

Apart from a brief field visit to collect palaeomagnetic samples and conduct two visiting Soviet scientists on an inspection of the Arunta Block, work on the Arunta project concentrated mainly on consolidating the results of investigations to date in maps and reports.

The Alligator Rivers party completed their investigations of the Mundogie 1:100 000 Sheet area, and continued shallow drilling to assist understanding subsurface stratigraphic correlations in areas of poor outcrop and to test airborne and ground geophysical anomalies. The party will continue to concentrate their field investigations on the western side of the Pine Creek Geosyncline next year.

Project and party leaders joined together in June in visiting each other's field project areas to examine stratigraphic correlations, discuss field methodology and rock nomenclature, and present their geological reconstructions with visits to critical outcrops. Fourteen geologists, including two geochronologists and two Geological Survey of Queensland geologists, spent about a week each in the Georgetown Inlier, the Precambrian of northwestern Queensland, the Arunta Block, and the Pine Creek Geosyncline. The tour was of great benefit and the exchange of views was found so worthwhile and necessary that a similar exercise will be undertaken from time to time, to aid proper correlations and enable consistency in field mapping practice to be achieved.

The Metalliferous Section continues to provide the geology for Antarctic studies. Work from last season resulted in additional collections being made of mineralogically interesting rocks, such as sapphirine-quartz rocks, that should be of critical importance in elucidating the temperature and pressure conditions of regional metamorphism in the area. In addition, petrological and lithogeochemical studies are continuing on eclogites, felsic gneisses, mafic dykes, and the ultrapotassic volcanic rocks of Gaussberg.

The detailed study of the Cainozoic volcanics in Papua New Guinea will be completed by mid 1979. Studies this year have concentrated on the regional tectonic implications of Quaternary volcanism, on gathering trace-element geochemical results for volcanic rocks, and on accounts of volcanic activity in Papua New Guinea.

Some geologists from the Metalliferous Section experienced in PNG geology will be involved in an Australian Government aid project to Indonesia, to assist with geological and geophysical mapping of Irian Jaya. During 1976 and 1977 they have been involved in planning and regional reconnaissance geological and geochemical field work.

The Metalliferous Laboratory was involved in several major and some minor projects. Ore genesis studies are currently in progress to establish a better understanding of uranium mineralisation processes in the Pine Creek Geosyncline and at Mary Kathleen. The lithogeochemical study of the Cullen Granite was completed and found, amongst other things, that a relation between the granite geochemistry and mineralisation is suggested only for uranium, copper, and tungsten.

Work continues on the study of kimberlites, carbonatites, and other alkaline ultramafic rocks in eastern Australia. Study of co-existing mineral phases in kimberlite pipe xenoliths has indicated abnormally high geothermal gradients in some parts of southeastern NSW.

Geochemical study of the Pilbara Archaean rocks is continuing as part of the Archaean Geochemistry International Geological Correlation Project. In addition, study of early crustal evolution, and interpretations based on increased worldwide knowledge of the Archaean rocks, has led to an expression of views on the radius of the Precambrian Earth which supports the expanding Earth hypothesis.

SEDIMENTARY SECTION

Head of Section: G.E. Wilford

PROVINCE STUDIES

CARPENTARIA AND KARUMBA BASINS

by

J. Smart

STAFF: J. Smart; K.G. Grimes (GSQ)

The main objectives of the Carpentaria and Karumba Basins project are to complete the reporting of the reconnaissance geological mapping of the basins and to produce a synthesis and analysis of the results. During 1977 outstanding 1:250 000 geological maps and explanatory notes for the Westmoreland and Mornington/Cape Van Diemen Sheet areas were prepared and the Bulletin synthesising the geology was finalised. A 1:1 million geological map of the two basins was revised and a second sheet prepared which includes cross-sections, and index maps showing structure, hydrogeology, geomorphology, topography, and Mesozoic geology. Both sheets will accompany the Bulletin. Grimes completed papers on the late Cainozoic evolution of the Carpentaria Plains, north Queensland (with H.F. Doutch) and on ancient land surfaces in the area. Smart published a paper on late Quaternary sea levels in the Gulf of Carpentaria. The project is a joint one with the Geological Survey of Queensland.

GEORGINA BASIN

Compiled by

J.H. Shergold

STAFF: J.J. Draper, E.C. Druce (part time), K.A. Heighway, J.M. Kennard, P.J. Kennewell (part-time), B.M. Radke (on study leave), J.H. Shergold, C.J. Simpson (part-time), R. Tracey, M.R. Walter (part-time), R.G. Warren (part-time), G.C. Young (part-time); P. Green (GSQ), P. West (ANU)

The aims of the Georgina Basin Project are principally to assess the regional relationships of Upper Proterozoic to Devonian stratigraphic

units, evaluate the biostratigraphic sequence, and construct a palaeo-environmental framework which will be helpful for interpreting the Late Proterozoic and Early Palaeozoic geography of the region. It is hoped that such studies will assist the search for petroleum, stratabound mineral deposits of Mississippi Valley type, and phosphate.

FIELD ACTIVITIES

Field work was conducted between early July and late September 1977. Activities included the field research over 1:100 000 Sheet areas of Adam, the northern half of Mount Barrington, and southern portions of Marqua and Toko (Walter, Simpson, Kennewell, Warren, Shergold), of Neeyamba Hill (Kennewell, Draper), of Mount Whelan (Draper, Green, and parts of Abudda Lakes (Draper Young)) (Fig. S2); the further investigation of the depositional environment and spatial distribution of the Arrinthrunga Formation (Kennard); and the collection of Devonian fish (Young).

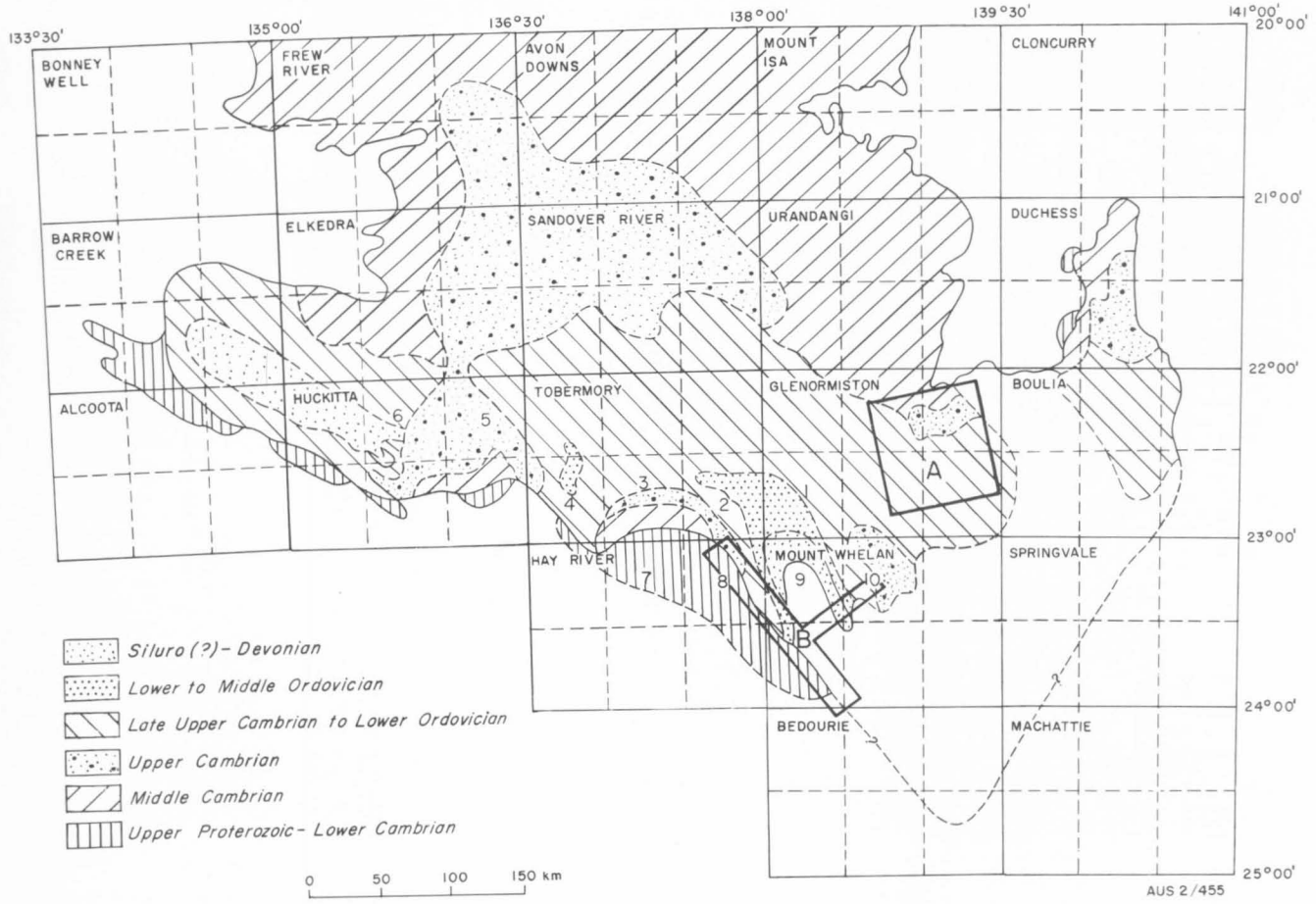
Drilling by BMR and the Geological Survey of Queensland (GSQ) has clarified the Proterozoic and Early Cambrian stratigraphy southwest of the Craigie-Toomba Fault System and south of the Marqua Monocline, and the relation between Sun Hill Arkose and overlying Middle and Upper Cambrian carbonate sequences north of Mount Whelan.

Stratigraphic drilling by GSQ has been tied to previously drilled deep exploratory oil wells, Netting Fence No. 1 and Ethabuka No. 1, by a BMR seismic survey. This survey is intended also to investigate the nature of the Craigie and Toomba Faults, and more accurately define the Mirica and associated structure to the southwest of Ethabuka.

An airborne magnetic survey has been flown over a portion of the Glenormiston 1:250 000 Sheet area, east of the Georgina River and northeast of 'Glenormiston' (Fig. S2), searching for the location of basement features which may have controlled Lower Palaeozoic sedimentation, for favourable environments for the formation of stratabound Pb-Zn deposits, to define the distribution of non-outcropping granite, and to define the western margin of the Mount Isa Block.

Results of field activities

1. Six areas of basement are recognised between the Hay River and the Toomba Range. Characteristically, basement consists of aluminous granite



1:100000 SHEET REFERENCE

1 NEEYAMBA HILL
2 TOKO
3 MARQUA
4 TARLTON
5 LUCY
6 ARAPUNGA
7 MOUNT BARRINGTON
8 ADAM
9 ABUDDA LAKES
10 MOUNT WHELAN

A Airborne Survey area
B Seismic Survey area

FIG.S2 Generalised geological map: Georgina Basin showing 1977 Survey areas (numbered 1:100 000 Sheets)

(muscovite-rich). In two areas metamorphic rocks are associated with the granite basement. Quartz-feldspar gneiss and two-mica schists occur near Mount Smith (Hay River) and muscovite-feldspar-quartz schistose gneisses occur to the southwest and southeast of "New" Marqua. These metamorphics are thought to correlate with Division 2 of the Arunta Complex (R.G.W.).

2. In the Adam 1:100 000 Sheet area basement granites and metamorphics are overlain by poorly outcropping arkose, and locally by stromatolitic dolomite; drilling has revealed green siltstone and shale in this interval. Above this, the Yardida Tillite* (over 1.5 km thick), is locally capped by thin dolomite beds. The Yardida Tillite correlates with the lower tillite of other Adelaidean basins. The Black Stump Arkose* lies disconformably on the siltstone and tillite, and is overlain by an, as yet, unnamed sequence of interbedded dolomite, siltstone, and shale. Above this the Wannadinna Dolomite* and Gnallen-a-gea Arkose* are correlated respectively with the Julie Member and lower Arumbera Sandstone of the Amadeus Basin. The Grant Bluff Formation is disconformably overlain by a bioturbated sandstone of Early Cambrian age (M.R.W.).

3. This bioturbated sandstone is disconformably overlain by a sequence of archaeocyathid bioherms, coquinite, tabular grey chert, and leached siltstone, of probable Ordian to Templetonian age, in the region south of Marqua Desert Bore. Along the southern margin of the Marqua Monocline, a limestone dolomite and chert sequence, of similar age, overlies pebbly arkose, probably unconformably. The contact is faulted at some localities, and at others the carbonate/chert unit is degraded and heavily silicified (silcrete horizon) . Rubble trains so formed contain the trilobite Redlichia, archaeocyatha, and nodules some of which contain pseudomorphs after a fibrous mineral - possibly gypsum or anhydrite. In some places the silicification of the carbonate sequence is associated with sulphide discoloration, quartz infillings of vugs are common, and the occurrence of free doubly terminated quartz crystals with occasional fluid inclusions is not infrequent at some places. Possibly the biohermal horizon has been invaded by hydrothermal fluids, and this activity has flushed evaporite from the overlying carbonate sequence, leading to collapse and brecciation before deposition of Templetonian siltstone (J.H.S.).

* Informal name yet to be defined

4. The Adam/ Mount Barrington/ Marqua/ Toko region is characterised by NW-trending structures. NW-trending faults are generally normal, but where they veer to the NNW or W at their northern ends, they change to low-angle thrusts, and are associated with monoclinal folds. The Toomba-Craigie fault system may be interpreted so.

A low-angle thrust fault, bringing Upper Proterozoic arkose in contact with Yardida Tillite at Aroota Bore, continues into the southern end of the Marqua Monocline.

Normal faults additional to those previously mapped have been mapped between the Toomba Range and the Plenty River.

Complex folding in the vicinity of Marqua Desert Bore is thought to result from the gravity sliding of Proterozoic units off granitic basement features (C.J.S.).

5. GSQ drilling north of Mount Whelan has revealed a tillitic sequence underlying Sun Hill Arkose equivalents, and overlying granitic basement. This sequence is overlain by Thorntonia Limestone (?) and Georgina Limestone. A second hole, about 5 km south of Carlo homestead, penetrated 914 m of Ordovician rocks on the eastern flank of the Toko Syncline. One difference between the sequence in this hole and Alliance Ethabuka No. 1 (30 km southwest) is the presence of 50 m of redbed Sandstones below the Coolibah Formation in the GSQ hole but not in Ethabuka No. 1. (J.J.D.).

6. Georgina Limestone south of 'Glenormiston' consists mainly of laminated peloidal grainstone. A bed of algal boundstone occurs within the unit, and intraformational conglomerate occurs throughout. Sandstone commonly occurs towards the contact with Ninmaroo Formation (P.G.).

7. In the Marqua area, the lower portion of the Arrinthrunga Formation consists of an ooid shoal or barrier bar (20-30 m ooid grainstone) behind which a series of seaward prograding lagoonal, intertidal, and supratidal sequences were deposited (400 m, lime mud, grainstone, dolomite, algal boundstone). The upper part of the formation represents a shallow subtidal environment characterised by domal algal boundstone.

In the Huckitta area, the formation consists of supratidal and sabkha sediments (algal dolomite and evaporite) overlain by intertidal and subtidal grainstone, lime mud, algal boundstone, and dolomite (J.M.K.).

8. Widespread subsidence of the Kelly Creek, Coolibah, Nora, and Tarlton Formations into solution cavities from several metres to several kilometres across which have developed in the Ninmaroo Formation can be demonstrated. Such features can lead to difficulty in airphoto interpretation (P.J.K.).

9. A large quantity of Devonian fish was obtained from outcrops of Cravens Peak Beds in the core of the Toko Syncline. This fauna is dominated by placoderms, but also includes crossopterygians, onychodontids, and acanthodians. A similar fauna occurs in limestone below Cravens Peak Beds arenites in the southern Toomba Range. The presence of Wuttagoonaspis in the Cravens Peak Beds permits correlations with the lower part of the Mulga Downs Group in western NSW and the lower Dulcie Sandstone in the western Georgina Basin (G.C.Y.).

LABORATORY ACTIVITIES

1. Geochemical studies continue: anomalous Zn values from the Arrinthrunga Formation in BMR Huckitta Nos. 7 and 8 are associated with sphalerite. The upper part of the Meeta Beds (equivalent to Arrinthrunga Formation) has anomalous values of Pb, Zn, and Ba. At Box Hole, lead, zinc, and barium mineralisation occurs at this stratigraphic level. A progress report on Georgina Basin geochemistry has been compiled (J.J.D.).

2. Depositional environments of the Toko Group have been analysed. Nora Formation represents offshore, below wave-base sediments; Carlo Sandstone represents barrier dunes or bars; and the Mithaka Formation represents lagoon bay sediments (J.J.D.).

3. The Early Palaeozoic geology of the Georgina Basin has been reviewed by Shergold and Druce, and its petroleum prospects assessed by Draper, Shergold, and Heighway. A bibliography of the basin has been com-

piled by Druce and Shergold. The 1974-75 stratigraphic drilling program has been synthesised by Kennard and Draper, with palaeontological appendix supplied by Shergold.

4. A computer file containing stratigraphic, geochemical, palaeontological, and petrological data is complete to the end of 1976. It presently contains 3329 elements representing a file with over 4.5 million characters (K.A.H.).

McARTHUR BASIN

by

K.A. Plumb

STAFF: K.A. Plumb, M.J. Jackson, M.D. Muir; K.J. Armstrong; M.C. Brown (Canberra College of Advanced Education); D. Large (Technical University of Braunschweig)

OBJECTIVES

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.

This will be carried out by:

(1) Revising the stratigraphic framework of the basin;

(2) Identifying the sedimentary environments in which the various units were deposited;

(3) Identifying the fossil assemblages of the basin, and determining their stratigraphic distribution and palaeoecology;

(4) Determining the origin and history of the geological structures;

(5) Studying the distribution, the stratigraphic, sedimentological, and structural setting, and the mineralogy, geochemistry, and fossil content of the mineral deposits of the basin;

(6) Detailed field observations in selected areas, and publishing the results at 1:100 000 or other appropriate scale, and revising existing 1:250 000 scale geological maps of the McArthur Basin.

The project will entail a long-term multidisciplinary study of the basin and its mineral deposits, by BMR and the Baas Becking Laboratory, with co-operation by CSIRO and industry.

OBJECTIVES OF 1977 PROGRAM

1977 saw the commencement of the McArthur Basin Project, and was seen as a familiarisation and reconnaissance year for those personnel new to the region.

The objectives of the 1977 field program were:

(1) Reconnaissance and familiarisation by the whole party of the regional stratigraphy and structure of the southern McArthur Basin;
(2) Familiarisation by the whole party with the types of mineral deposits in the southern McArthur Basin;
(3) Measurement of a detailed composite stratigraphic section through the McArthur Group;
(4) Detailed field observations in selected areas to assess the types of lateral changes present, and the detail required for future planning.

BASIC OUTLINE

The McArthur Basin is a relatively undeformed structure containing up to 12 km of unmetamorphosed Carpentarian sediments, which are exposed over about 170 000 km^2 in the Northern Territory, and a small part of northwestern Queensland, around the western and southwestern sides of the Gulf of Carpentaria. Its general stratigraphic and structural framework was outlined by BMR's 1:250 000 mapping program during 1958-1962. This has since been supplemented and locally modified by the work of mineral exploration companies, particularly Carpentaria Exploration Company, and others, and which has led to a major revision of the stratigraphy of the McArthur Group.

The basin contains the large McArthur River (or H.Y.C.) zinc-lead deposit, which is achieving increasing prominence as a model for stratiform sulphide mineralisation, and several other scattered occurrences of

lead, zinc, and copper which indicate potential for further discoveries of economic mineralisation. The basin contains probably the thickest and most extensively exposed sequence of unmetamorphosed Carpentarian rocks in Australia, providing an excellent opportunity to study the evolution of a basin of this age, and of the geological setting and origin of the strata-bound mineral deposits within it.

1977 ACTIVITIES AND RESULTS

Introductory tour

K.A. Plumb conducted a tour across the Wearyan Shelf and southern Batten Trough, from 15 to 25 August, for all personnel presently involved, or with potential future involvement, with the project. Most units of the Tawallah, McArthur, and Roper Groups were studied, the regional tectonic and stratigraphic setting assessed, and the major mineral deposits visited.

Personnel taking part were: K.A. Plumb, M.J. Jackson, M.D. Muir, M.R. Walter, A.R. Jensen, J.F. Truswell, C.J. Simpson, A.T. Wells (BMR); I.B. Lambert (Baas Becking Laboratory); N. Williams, R. Logan, M. Neudert (ANU); D.J. Sangster (Geol. Surv. Canada); D. Large (Technical University of Braunschweig).

Section measuring

Twenty-three detailed stratigraphic sections, totalling about 3750 m of section, were measured during 1977; localities are summarised in Figure S3. Combined with sections measured in the last few years through the Emmerugga Dolomite, Teena Dolomite, Barney Creek Formation, and Reward Dolomite (Nos. MCB 1-14), and the Amelia Dolomite (A1; M7-12), at least one complete section has now been measured through all units of the southern McArthur Basin, except the Looking Glass and Smythe Formations.

Sections measured during the original 1959-62 survey generally are not comparable with the later work, owing to lack of detail and changed interpretations of features, and are disregarded here. Many of the sections measured during 1977 (K1-12) are known to be thinner than the same units elsewhere, but were selected for initial work because of good exposure.

Sections measured during 1977 were:

Dungaminnie Formation (M6) - 243 m + (no base exposed; probably 50 m unexposed). Dolarenite and sandstone; siltstone and fine-grained sandstone; Conophytons in dolarenites.

Balbirini Dolomite (M5) - 927 m. Thin-bedded dolarenite; local stromatolite beds of great variety. Siltstone intervals; minor sandstone; abundant black chert; several stromatolite and evaporite marker beds.

Amos Formation (M4) - 87 m. Red-brown sandstone and siltstone with slump structures; detrital dolomite with characteristic stylolites; oncolites. A newly discovered unconformity now separates the Amos Formation from the Balbirini Dolomite.

Stretton Sandstone (M3) - 179 m. Flaggy, wavy-bedded, fine-grained feldspathic sandstone and siltstone. Abundant shale clasts and distorted mud cracks.

Yalco Formation (M3) - 168 m (Partial sections G3 - 50 m; G4 - 50 m).

Cherty dolomite; chert nodules and bands. Stromatolites, teepee structures. Ripple-drift bedded, fine-grained dolomitic sandstone.

Lynott Formation (G2) - 625 m (Partial sections M1 - 160 m; M2 - 103 m).

Donnegan Member - 134 m - Ripple-drift bedded, purple-brown, fine-grained sandstone and siltstone; minor dololutite. Abundant "cauliflower cherts". Some stromatolites, teepee structures.

"Middle Lynott" - 332 m - Laminated and ripple-drift bedded, dolomitic siltstone and fine-grained sandstone; stromatolitic dololutite and chert; coarse-grained dolomitic sandstone.

"Lower Lynott" - 159 m - Slumped, laminated, dolomitic siltstone and pyritic siltstone. Slump breccia.

Reward Dolomite (G1) - 70 m. Dolomite breccia. Graded-bedded dolarenite and dololutite. Cherty dolomite. Slump structures. Stromatolites locally.

Emmerugga Dolomite - Partial sections, Mara Dolomite Member (K1 and 6, K4-5) - 115 m. Stromatolitic and cherty dolomite.

Tooganinie Formation - 362 m. Stromatolitic dolomite; dolomitic shale and sandstone; flake breccia; ooliths.
Myrtle Shale Member (K8) - 63 m
Leila Sandstone Member (K8) - 30 m.
"Lower Tooganinie" (K2-3; K7) - 269 m.

Tatoola Sandstone (K9) - 90 m. Flaggy dolomitic sandstone and siltstone. Characteristically mud-cracked, tool-marked, wavy-bedded.

Amelia Dolomite (K10) - 181 m. Stromatolitic dolomite; flake breccia. Minor red and purple shale ooliths.

Mallapunyah Formation (K11, K12) - 239 m. Red siltstone and sandstone. Minor stromatolitic dolomite. "Cauliflower chert".

Evaporite minerals

Before 1972, halite casts were known to be abundant in several units, and gypsum casts had been identified from the Tatoola Sandstone, but no other evaporites had been identified. Several unusual beds, since identified as replacements of evaporites, had been mapped, but their origin was not understood.

Much more extensive evaporite relicts have recently been identified and even more extensive occurrences identified during 1977. Few of the original evaporite minerals are preserved in their original state; they are now pseudomorphed by later minerals.

The 1977 field work has greatly extended the range of occurrences and almost all formations in the McArthur Group are now known to contain evaporites. They are important palaeoenvironmental indicators, and their possible contribution to the origin of mineral deposits in the region will form an important facet of the McArthur Basin Project.

The types of occurrences identified and the units containing them (brackets indicate minor occurrences) are:

Halite casts on bedding planes - Dungaminnie Formation, (Balbirini Dolomite), (Lynott Formation), Teena Dolomite, Mara Dolomite Member, Tooganinie Formation, Tatoola Sandstone, (Amelia Dolomite), Mallapunyah Formation.

Discoidal and euhedral gypsum and/or anhydrite pseudomorphs - Balbirini Dolomite, Lynott Formation, Donnegan Member, (Tooganinie Formation), Tatoola Sandstone, Amelia Dolomite, Mallapunyah Formation.

Pseudohexagonal laths after ?gypsum - Lynott Formation, (Emmerugga Dolomite).

Radiating acicular gypsum clusters - Coxco Dolomite Member, (Reward Dolomite), (Mara Dolomite Member).

"Cauliflower chert" nodules after anhydrite - Donnegan Member, Mallapunyah Formation, (Balbirini Dolomite), (Lynott Formation),

Sideritic marble replacement of massive gypsum and/or anhydrite - Amelia Dolomite, Balbirini Dolomite, (Lynott Formation), (Tooganinie Formation).

Environmental interpretations

The studies are only at a very preliminary stage at present, and only provisional interpretations are possible, but it is already clear that the greater part of the McArthur Group (up to 5.5 km cumulative thickness) was deposited in very shallow seas or lakes; a great deal of it, in fact, was intertidal and supratidal. Only the Barney Creek Formation, parts of the Reward Dolomite, "Lower Lynott Formation", and perhaps Amos Formation, show evidence of relatively deeper water.

Mineral deposits

The striking feature of the mineralisation within the McArthur Group is its general strata-bound nature. Recent work by Carpentaria Exploration Company and the 1977 BMR field work has led to revision of the stratigraphic setting of many of the deposits. Although some work is still very preliminary, the currently considered host units of the mineral deposits (Figure S3) are:

Balbirini Dolomite - Eastern Creek Pb-Ba (Mount Young Sheet)

Reward Dolomite - Reward Pb, Cooks Zn-Pb, Cox Zn-Pb, (?)Darcy's Cu, (?)Yah Yah Cu.

Cooley Dolomite Member - Ridge Zn-Pb

H.Y.C. Pyritic Shale Member - McArthur River (H.Y.C.) Zn-Pb, W-Fold/Wickins Hill Zn-Pb

Mara Dolomite Member - Cooley Cu-Pb-Zn, Turnbulls Cu, Squib Cu.

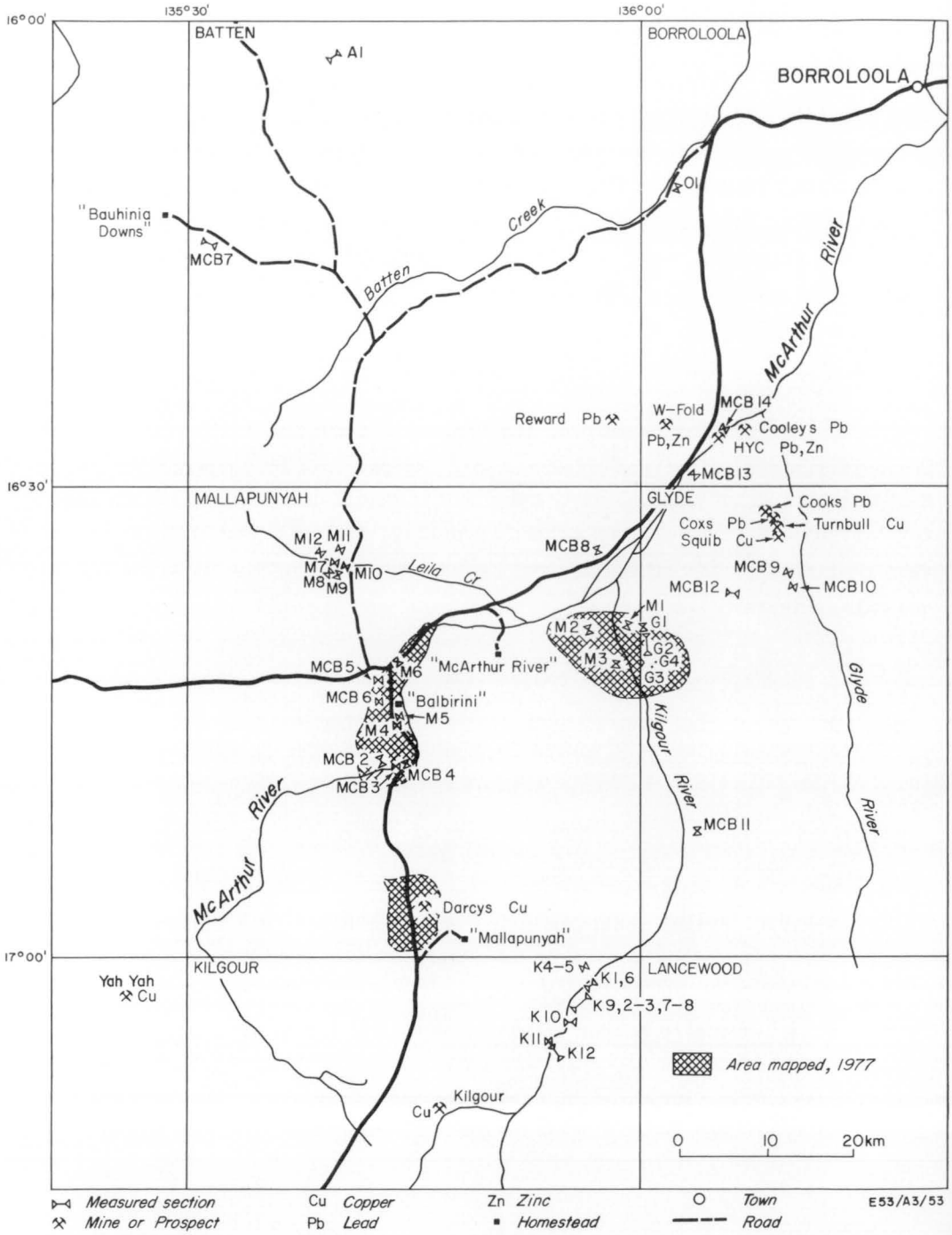


FIG.S3 Locality map Bauhinia Downs and northern Wallhallow 1:250 000 Sheet areas, showing 1:100 000 Sheets

Amelia Dolomite - Kilgour Cu, Coppermine Creek and Sly Creek Cu (Mount Young Sheet area).

WISO BASIN

by

P.J. Kennewell

STAFF: P.J. Kennewell (October 1976-July 1977), S.P. Mathur (part-time), P.G. Wilkes (part-time).

The Wiso Basin project aims to produce six 1:250 000 scale geological maps and explanatory notes, and a bulletin summarising the geology of the whole Basin.

During 1977 the final two geological sheets (Lander River and Green Swamp Well) with accompanying explanatory notes were completed and passed to the editors. A first draft of the Bulletin was completed, and compilation of a 1:1 million scale map to accompany the Bulletin was started. A paper synthesising the geology and geophysics of the Lander Trough was completed and published in the BMR Journal.

CANNING BASIN

by

R.R. Towner

STAFF: R.R. Towner, D.L. Gibson, D. Walton, D. Green (BMR); R.W.A. Crowe (GSWA)

The reconnaissance geological field research of the Palaeozoic and Mesozoic Canning Basin, Western Australia, was begun in 1972 and the field-work completed in 1977. The main objectives of the project are to prepare 22 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 of each season's fieldwork and to publish a brief synthesis and 1:1 million geological map of the basin, and papers on specific aspects of the geology. The project is a joint one with the Geological Survey of Western Australia. The Basin Study Group, BMR provides assistance with subsurface interpretations.

By October 1977, seventeen of the thirty-four 1:250 000 maps and Explanatory Notes had been completed; of these five had been published and twelve were in press or with editor. Five Records have been issued: three describing results of the previous field seasons (1975/77; 1976/24; 1976/95), one describing the plant fossils (1976/18) and the other the macrofossils (1974/77) collected during 1972-73.

Between 7 June and 20 August 1977, the party carried out field research over eleven Sheet areas in the western part of the Canning Basin bordering the Indian Ocean. The observations were carried out on 1:80 000 and 1:50 000 scale aerial photographs using Landrovers and a helicopter.

A provisional interpretation of the solid geology of these areas and a rock relationship diagram are presented in Figures S4 and S5 respectively.

The preliminary results indicate that:-

1) the distribution of many units differs considerably from that shown on the existing geological maps (e.g. the 20 miles to 1 inch map of Veevers & Wells, 1960);

2) all outcrops previously assigned to the Neocomian Jowlaenga Formation can be identified with either the Jarlemai Siltstone, Broome Sandstone, or Melligo Sandstone; therefore, the Jarlemai Sandstone may range into the Neocomian (Early Cretaceous);

3) there is no evidence for an erosional break between the Melligo Sandstone and the Broome Sandstone (previously Jowlaenga Formation) as suggested by early workers as these two formations interfinger at Dampier Hill, One Arm Point, and in the Cygnet Bay region;

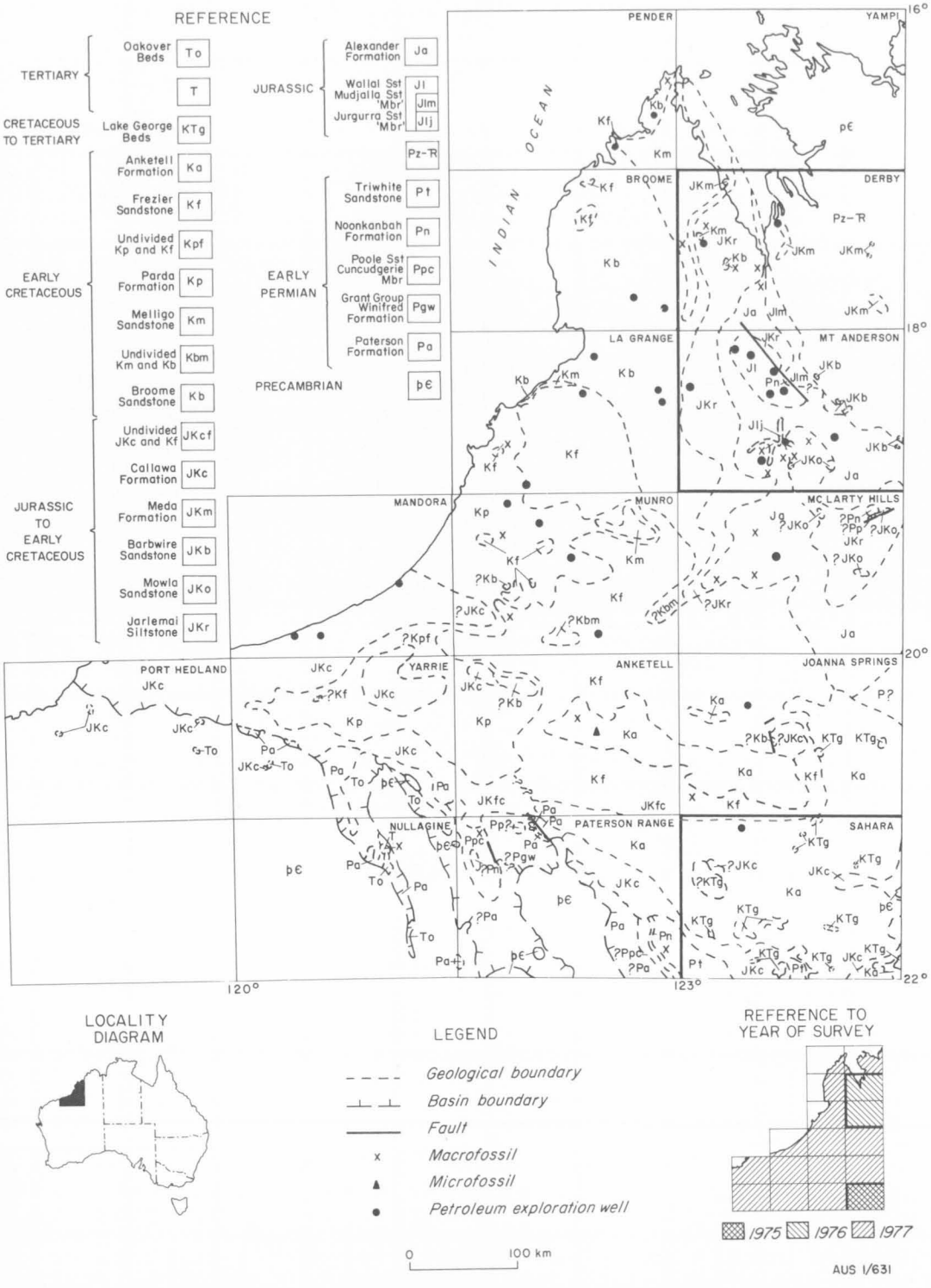


FIG.S4 Preliminary geological interpretation of West Canning Basin
For stratigraphic relationships of units see FIG.S5

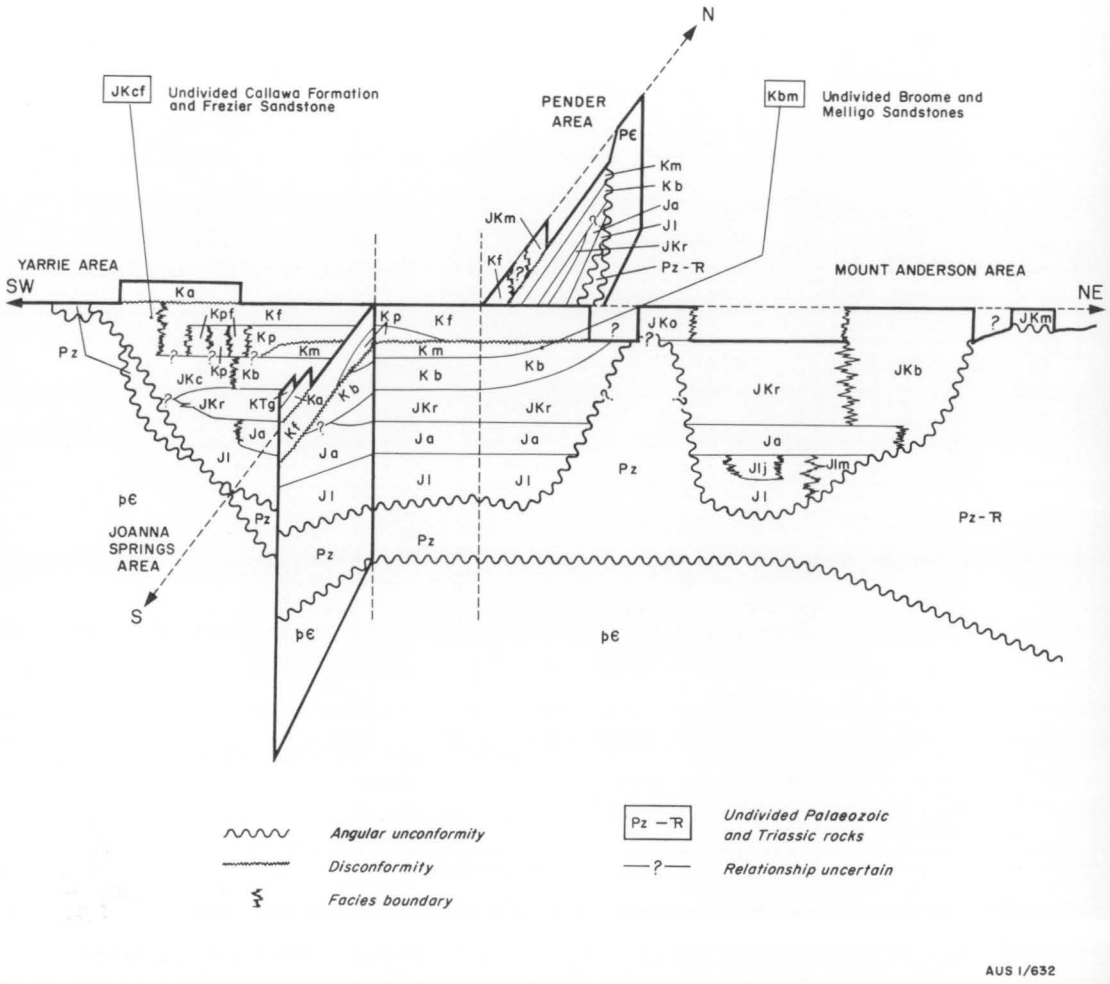


FIG.S5 Stratigraphic relationships of West Canning Basin
For unit names and distribution see FIG.S4

4) the Melligo Sandstone is not everywhere silicified as claimed by Brunnschweiler (1957);

5) the Broome Sandstone was deposited in several environments ranging from deep water to shallow water marine (possibly tidal deposits, with channels and sand bars). It thickens markedly to the west;

6) the Leveque Sandstone which is only exposed at Cape Leveque is equated with part of the Broome Sandstone;

7) the Melligo Sandstone in the Dampier Peninsula accumulated as a beach or barrier bar which migrated westwards with regression of the Jurassic-Cretaceous sea;

8) the Pender Bay Conglomerate is an unconsolidated soil blanketing an erosion surface on Emeriau Sandstone; it contains reworked boulders of the latter. It is therefore not equivalent to the Emeriau Sandstone as suggested by Brunnschweiler (1957);

9) the outcrop on Valentine Island tentatively assigned by Brunnschweiler (1957) to the Pender Bay Conglomerate can be identified with the Meda Formation. This outcrop overlies Aptian Melligo Sandstone and therefore the Meda Formation is at least partly of Cretaceous age;

10) the Emeriau Sandstone is lithologically similar, and occupies a stratigraphic position similar to the Cretaceous Frezier Sandstone; the Emeriau Sandstone is therefore probably Cretaceous;

11) the Melligo Sandstone has been recognised in the southwest and central part of the area where it is overlain by the Parda Formation; these formations comprise a barrier bar/lagoon bay system in this area;

12) the discontinuous lower part of the Frezier Sandstone is a fossil soil, which passes laterally into the Parda Formation; the fluviatile upper part overlies the Parda Formation. The Frezier Sandstone was probably deposited in a delta which drowned the lagoon/bar system in which the Parda Formation was deposited;

13) although an actual contact was not located, a time gap probably occurred between the continental Frezier Sandstone (deposited after the westward regression of the Jurassic-Cretaceous sea), and the paralic Anketell Sandstone (deposited by the northwesterly transgression of the Cretaceous 'Officer Basin' sea);

14) drilling by GSWA along the southern margin of the basin shows that the Jarlemai Siltstone pinches out at depth near the basin margin;

15) the Callawa Formation lies stratigraphically above the Jarlemai Siltstone and is a fluviatile basin margin equivalent of the Cretaceous Broome, Melligo, and Frezier Sandstones and the Parda Formation; the Callawa Formation is therefore of Cretaceous and possibly Jurassic age;

16) the Broome and Melligo Sandstones in places contain appreciable amounts of heavy minerals; small concentrations of these heavy minerals, apparently eroded from these sandstones, are present in some beaches north of Broome.

NGALIA BASIN

by

A.T. Wells

STAFF: A.T. Wells; F.J. Moss (Geophysical Branch)

The objective is a review of the available geological and geophysical information on the Ngalia Basin, and publication of the results in the BMR Bulletin Series. During 1977 all seismic and gravity data were re-interpreted and the results analysed and a short field visit was made to further study some Proterozoic units.

Structure and palaeotectonics from geophysics

All seismic data in the basin were re-interpreted, commencing with basic record sections from BMR and Company files. Three prominent reflection events of varying quality and continuity were plotted over most of the basin covered by surveys. A detailed analysis was made on several north-

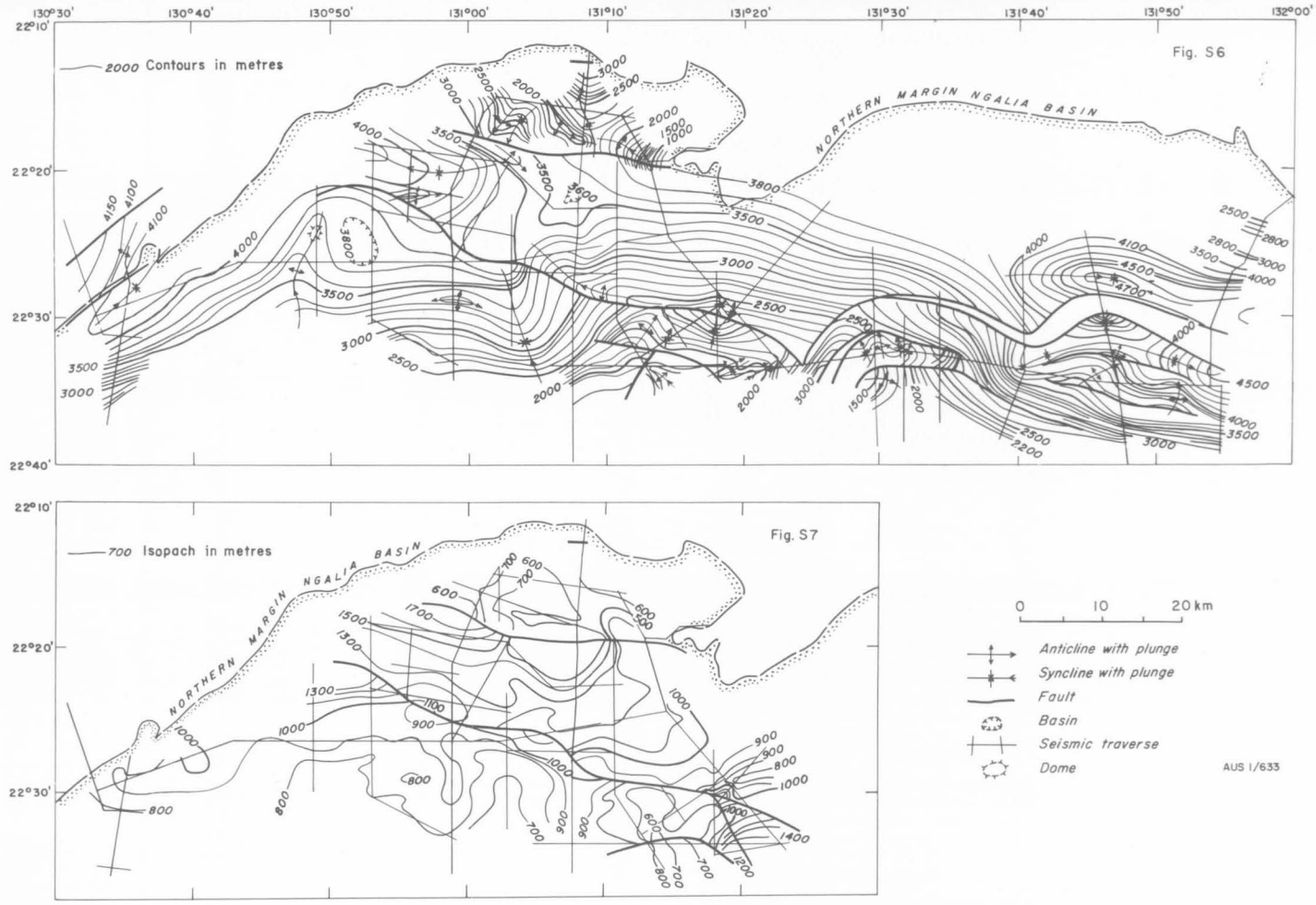


FIG.S6 Structure countours, near base Vaughan Springs Quartzite, Ngalia Basin, N.T. (Based on migrated depths from seismic surveys)

FIG.S7 Lower Palaeozoic isopachs, Ngalia Basin (Interpreted from seismic surveys)

south traverses where increased data quality and quantity permitted. All discernible and reasonably continuous reflection data were used on these lines. Reflections were timed at each shot point and the data computed using program DIPMIS; migrated depths, corrected positions relative to each shot point, and dips were listed in the printout. Six structure contour maps (time and migrated depths for the three horizons), two interval maps, and several detailed cross-sections were compiled from the data.

The deepest of the three prominent reflections is acoustic basement interpreted as being near the base of the Vaughan Springs Quartzite. The intermediate reflection is interpreted to be at or near the top of the Proterozoic sequence and the shallow reflector the base of the Upper Palaeozoic sequence. Structure contours on the deeper level are shown in Figure S6 and the Lower Palaeozoic isopach map (from intermediate to shallow reflection) in Figure S7.

The re-interpretation has elucidated the structure and palaeotectonics of the western and central parts of the basin which has negligible surface expression. Interpretation of the sequence of major faulting has been made using palinspastic restorations and has shown that several distinct movements, both normal and reverse, have occurred along ancient fractures. Many of the structures in the north can be continued with the major structures apparent in outcrop but those in the south have no surface expression. The Mount Doreen Fault, for example, which has been traced for 60 km on seismic records, cuts diagonally across the western part of the basin but has no surface expression. Of the four major structural subdivisions elucidated from the reprocessed seismic data, and apparent from the structure contour map (Fig. S6), only the northernmost can be related to structure in outcrop.

Lower Palaeozoic rocks, previously postulated to be absent in the western part of the basin, are now considered to be represented by a wedge of sediments with a maximum thickness of 1700 m preserved in the central trough. Southward thinning of this wedge is caused by units thinning within the interval and is probably a primary depositional feature.

Several closed structures are indicated and, together with the strong indication of a thick Palaeozoic sequence, considerably enhance the petroleum potential of the basin.

Field work

A brief field reconnaissance was undertaken with the objective of establishing a stratigraphic correlation between Proterozoic units in the southern Georgina, Amadeus, and Ngalia Basins (Table S1 - Information on new stratigraphic nomenclature in the southern Georgina Basin is from M. Walter and J. Shergold, BMR). Sections suitable for palaeomagnetic and magneto-stratigraphic studies by RSES were selected and in the course of this work new stratigraphic information was obtained. Several Precambrian sedimentary formations and quartz-hematite dykes were outlined for remnant magnetisation studies.

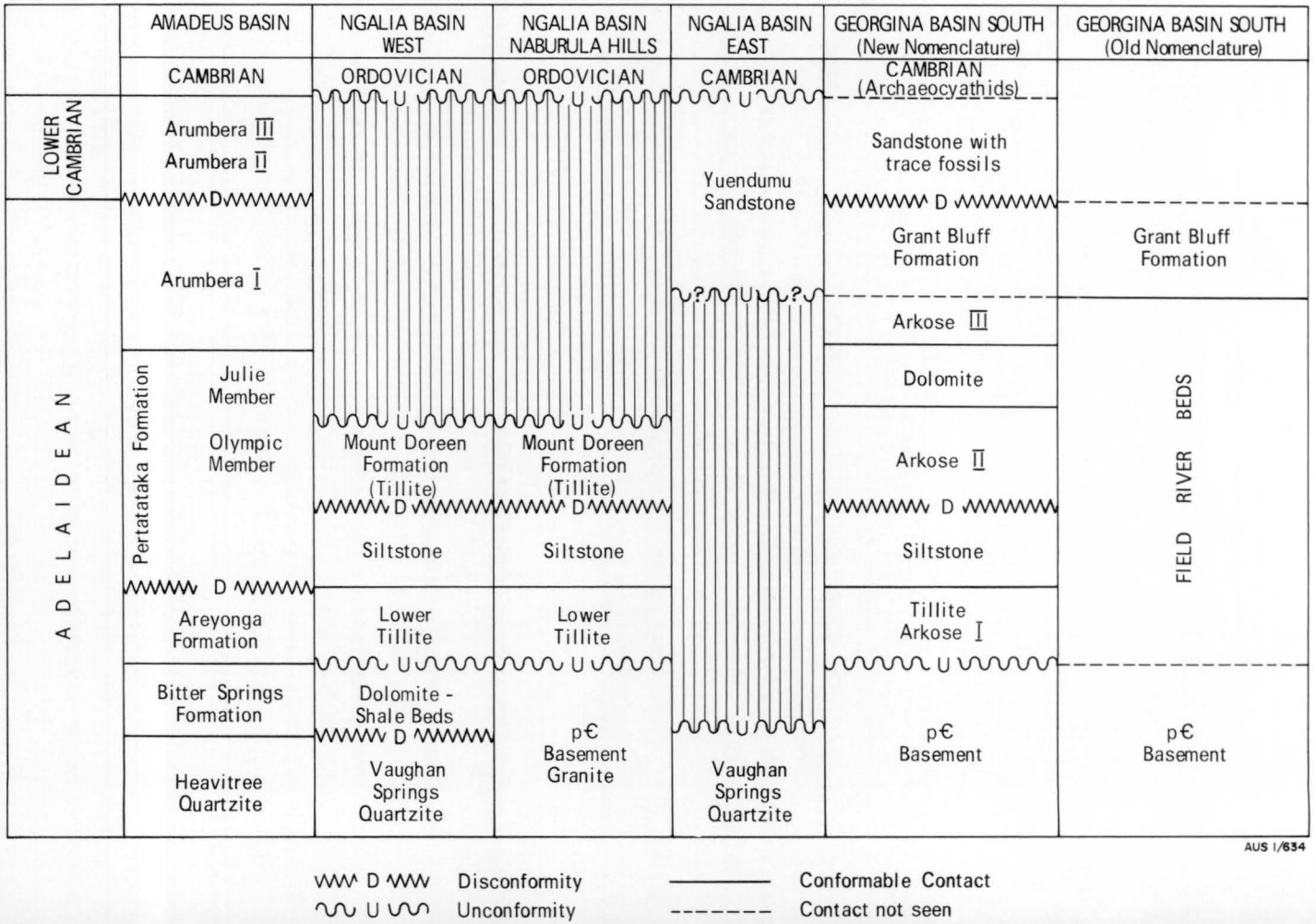
The new stratigraphic information obtained is summarised below.

(1) A second Proterozoic tillite level older than the Mount Doreen Formation (Lower Tillite in Table S1) was discovered in the Naburula Hills. The formation is about 8 m thick and non-conformably overlies Precambrian basement granite. The only other occurrence of the tillite found during this reconnaissance is in the northwest flank of the Vaughan Springs Syncline, where it overlies the Vaughan Springs Quartzite.

(2) Foetid stromatolitic dolomite, in places with black chert and shale in the SW Vaughan Springs Syncline and Treuer Range, which were previously mapped as the lower part of the Mount Doreen Formation, is considered to be the preserved remnant of an older formation (Dolomite-shale beds in Table S1). A nodular, mottled ferruginous and silicified zone at the contact of these beds with the Vaughan Springs Quartzite is possibly a fossil soil profile. The black chert in the beds will be examined for possible microfossil content.

(3) Previously undected trace fossils and a variety of sedimentary structures were discovered in recent excavations in the Yuendumu Sandstone. The fossils indicate that at least the uppermost beds in the formation are earliest Cambrian in age.

TABLE. S1 STRATIGRAPHIC CORRELATIONS OF PROTEROZOIC ROCKS IN THE NGALIA, AMADEUS, AND GEORGINA BASINS



(4) The eastern end of the Yuendumu Fault and quartz-filled fault zones in the Naburula Hills show evidence of sinistral shearing as well as a strong north-south component. It has been postulated that there has been recent re-activation along many of the basin faults and these may reflect the response of the continental crust to strong north-south compression. The allied study of palaeomagnetism of the quartz-hematite dykes along the southern margin of the basin may help to resolve this hypothesis.

(5) Stromatolites were discovered and collected from beds of dolomite in the upper part of the Mount Doreen Formation in the eastern Treuer Range area.

(6) Leptophloem ?australe, the first known occurrence in the Mount Eclipse Sandstone, was shown to the author by geologists of Central Pacific Minerals. The locality is about 55 km east of Bigryli Waterhole.

The new stratigraphic information obtained as a result of this reconnaissance, together with the formalised new names, will be incorporated in the Bulletin.

OFFICER BASIN

by

M.J. Jackson

STAFF: M.J. Jackson

The main objectives of the Officer Basin project are to understand the geology of the Western Australia part of the Officer Basin and to publish the results in the form of: twenty 1:250 000 geological maps and Explanatory Notes, a Bulletin synthesising the geology of the whole area accompanied by 1:1 million geological and geomorphological maps, and papers on specific aspects of the geology. The project is a joint one with the Geological Survey of Western Australia. Geological mapping was done in 1970 and 1971, and shallow stratigraphic drilling and geophysical work in 1972. Reporting of results started in 1973.

During 1977 the 1:1 million geological and geomorphological maps were drawn for preliminary editions and a first draft of the Bulletin was written.

EROMANGA BASIN

by

B.R. Senior

The final draft of the Eromanga Basin Bulletin was checked together with all the artwork before its despatch to the printer. Topics of special interest which could not be discussed adequately within this bulletin were prepared for separate publication. These are an account of the geology and magnetic characteristics of the southwest Queensland precious-opal deposits and the stratigraphy and palynology of the Jurassic to Early Cretaceous sedimentary rocks of the northeast basin margin, the latter in co-operation with D. Burger.

LACHLAN FOLD BELT (CANBERRA AREA)

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

The Lachlan Fold Belt Project 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 relation 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 1977, reporting on the Tantangara and Brindabella 1:100 000 Sheet areas was completed, field work on the Canberra 1:100 000 Sheet continued and fieldwork on the Araluen 1:100 000 Sheet was commenced. The Braidwood and Michelago Sheet areas have been mapped by the Geological Survey of New South Wales.

Tantangara-Brindabella Sheet areas (M. Owen, D. Wyborn)

The Tantangara-Brindabella Mapping Project was commenced in 1971 with the aim of producing geological maps of the two 1:100 000 Sheets,

primarily to improve basic knowledge of the geology of an important part of the Lachlan Fold Belt, but also to investigate the mineralisation of the area, and to provide a geological framework for possible urban geology investigations connected with the growth of Canberra.

Fieldwork was completed on the two Sheets in 1974 and a descriptive bulletin has been in preparation since. By October 1977 writing of this had been completed and it had been submitted for supervisor editing. Concurrent with the preparation of the bulletin, extensive revision of the preliminary edition geological maps was undertaken, and these were also submitted for editing.

A feature of the project has been the emphasis on whole-rock geochemistry, and over 320 samples have been analysed for major elements plus 17 trace elements. The application of this work to the Silurian acid volcanics of the Canberra-Yass Shelf has been particularly helpful in unravelling the many stratigraphic problems associated with these rocks. As mentioned in the annual summary for 1976, individual units of acid volcanics west of Canberra each have a distinctive mineralogy. Study of their chemistry also reveals significant differences. Those volcanics which contain cordierite and garnet as phenocryst phases (Paddys River Volcanics and Walker Volcanics) have a chemistry typical of S-type granitoids while those volcanic units lacking cordierite and garnet but containing sanidine (when silica is 70%) and allanite, have chemistry typical of I-type granitoids, particularly those of the Kosciusko Batholith.

Further, whenever stratigraphic control is present, the volcanics with I-type characteristics are always younger than the S-type volcanics, which parallels the situation for the granitoids of the Kosciusko and Berridale Batholiths. This change in chemistry from S- to I-type in the Yass area occurs at the level of the Yass Subgroup, while in the Canberra area it occurs at the level of the Yarralumla Formation, thus suggesting that the two units may correlate with each other. Thus all volcanic units in the Canberra-Yass-Uriarra region with S-type chemistry and associated mineralogy are considered to be older than the Yass Subgroup-Yarralumla Formation horizon, while those with I-type characteristics are considered to be younger.

Araluen Sheet area (M. Owen, D. Wyborn)

In May 1977 field research in the Araluen 1:100 000 Sheet area was commenced. The purpose of this project is to complete the geology of the Canberra 1:250 000 Sheet area at 1:100 000 scale and at the same time extend knowledge of the Palaeozoic history of the Lachlan Fold Belt.

Initially one month was spent on a reconnaissance of the whole Araluen Sheet area to determine access problems and the quality of previous mapping. Many deficiencies were found in the existing map in the Deua River area, where much of the country is underlain by unmapped subaerial felsic ignimbrites unconformably overlying Ordovician quartz-rich flysch. Field research on the Boro and Braidwood Granites indicates they are both composite bodies, and in particular a large pluton in the Araluen valley is more felsic than the rest of the Braidwood Granite. Basic dyke swarms are common; in the Boro Granite and the southern part of the Braidwood Granite some of these dykes are alkaline and probably of Cretaceous or Tertiary age. One alkaline stock has been discovered at Mount Donovan. It is vertically zoned from alkali gabbro to quartz monozonite at the top.

Systematic field research commenced in the northwest corner of the Sheet area in early October 1977 and will continue until May 1978.

Canberra Sheet area (R.S. Abell)

Field evaluation of the geology of the Canberra 1:100 000 Sheet continued and by October 1977 approximately 75% of the area had been covered. Field checking is scheduled for completion by Easter 1978 and reporting by early 1980. Notes on the geology of the area are given below.

ORDOVICIAN. This sequence consists of distal flysch with a few beds of laminated black slate near the top. Observed sedimentary structures (graded, disrupted and current bedding) are typical of sediments laid down in a turbiditic environment. The sporadic development of knotted schists and biotite segregation laminae in pelitic and psammitic schists support a phase of high-grade regional metamorphism.

SILURIAN. Sediments of this age show a greater variety of lithological types. In the Canberra trough a sequence of mudstone, siltstone, and arenite with scattered small lenses of limestone grades upwards through volcaniclastic sediments into a thick pile of acid volcanics. The Upper Silurian acid volcanics exposed around Canberra consist of a thick sequence of massive and banded dacitic to rhyodacitic porphyries, tuffs, agglomerates, and breccias. The volcanic sequence is interrupted by intercalations of tuffaceous sandstone, siltstone, shale and impure limestone, indicating that the essentially subaerial ignimbrite pile interfingered with surrounding marine sediments.

In the Captains Flat trough a much-reduced occurrence of acid volcanics in the sedimentary succession indicates that the dominance of volcanic activity evident in the Canberra region had decreased eastwards with the development of deeper water conditions. At Kennys Point an outcrop of banded acid volcanics containing large unorientated clasts of basalt rests on an irregular surface of basic volcanics. This suggests that during the Upper Silurian a phase of bi-modal volcanism existed in which acid and basic magma were extruded, probably in a tensional structural environment.

INTRUSIVE ROCKS. Acid intrusions are confined to small N-trending bodies of biotite granite and dykes of quartz feldspar porphyry, which postdate Upper Silurian sediments and acid volcanics. Basic igneous activity appears to have spanned a large time interval, since the amphibolites and hornblende gabbros of the Lochart Basic Complex (thought to be Early Silurian in age) have been extensively invaded by the Boro granite, and some acid intrusives have been cut by dolerite dykes.

STRUCTURE. A major deformational event (F_2 - Bowning?) seems to have occurred at the end of the Silurian or possibly early in the Devonian. Ordovician and Silurian sediments have fold axes and cleavage striking approximately N-S. Acid intrusions, volcanics and basic rocks also show a foliation and shearing trending in a similar direction. The status of an early F_1 fold phase needs further evaluation but some evidence for its existence can be deduced. Thus an inter-Silurian unconformity (Quidongan?)

in the Canberra region has M-U Silurian strata resting unconformably on folded Upper Ordovician or Lower Silurian rocks in which downward-facing beds are commonplace, although apparently unknown in the M-U Silurian. In an exposure of Ordovician schistose flysch in Turallo Creek, boudinaged quartz veins and biotite segregation laminae (F_1?) have been tightly folded, with the development of an axial planar F_2 cleavage. A dolerite dyke cross-cutting these folded F_1 segregation laminae has been foliated parallel to the F_2 cleavage.

STRATIGRAPHY. There are about 50 stratigraphic names in current use that could be applied to this Sheet. Many of the functional names do not appear to have any properly recorded definition although detailed descriptions have been given at "type localities" where the best exposures exist. In many cases owing to poor exposure and structural complexity, it is doubtful if the stratigraphic divisions proposed can be adequately demonstrated within the limits of the Australian Code of Stratigraphic Nomenclature. Where a detailed local stratigraphy has been erected it has been difficult to recognise it and apply it at a regional level. It is proposed to investigate the stratigraphic terminology in use in an attempt to rationalise the stratigraphy. This may entail dropping some of the existing stratigraphic units or grouping them into larger functional units.

1:250 000 GEOLOGICAL SHEET. At this stage attention is drawn to some of the mapping errors in the Canberra 1:250 000 geological map. Two of the most important within the limits of the Canberra 1:100 000 Sheet are: (1) the Tuggeranong Granite (gin) has now been classed as Upper Silurian dacitic porphyry and tuff; (2) there is a major change along the eastern margin of that Sheet, where the Lochart Basin complex can be mapped as a narrow N-trending belt extending from Forbes Creek to Ellenden on the eastern shore of Lake George. This replaces a narrow zone of acid volcanics (Sv) south of Lochart, and sundry "granite masses" which encroach into the Sheet area from farther east.

DETAILED STUDIES

CAINOZOIC STUDY GROUP

by

E.M. Truswell

During 1977, an informal study group was formed within BMR, with the aim of integrating research on Australian continental Tertiary deposits. Group members include B.R. Senior, M. Idnurm, and E.M. Truswell (E.M. Kemp).

As part of the group's activities, palaeomagnetic weathering studies initiated in 1975 in the Eromanga Basin were extended to other parts of the continent. This work is described below.

Palynology provides an additional means of time-control on the geological events which have influenced continental Australia during the Tertiary, and also provides data on climatic conditions. This may usefully be integrated with information derived from palaeomagnetism to provide an increasingly complete picture of Tertiary environments.

During 1977, work continued on the palynology of lignites from Ti Tree and Hale River, in the southern part of the Northern Territory. A review paper, in which Tertiary climatic data from deep-sea sources south of Australia are integrated with palynological data relating to the vegetation history of continental Australia, was completed early in the year. Periods such as the Paleocene-Eocene and the early Miocene, for which a warm, wet climate is evidenced from marine and palynological sources, coincide with intervals of intense weathering suggested by palaeomagnetic dating of profiles. In another study, undertaken in collaboration with R.W. Galloway of CSIRO Land Use Research, a closer examination has been made of Australian environments in the interval from the early Miocene to the Recent.

PALAEOMAGNETIC DATING OF CAINOZOIC WEATHERED PROFILES

by

B.R. Senior

STAFF: B.R. Senior; M. Idnurm (Geophysical Branch)

The purpose of this project is to determine the ages of weathering episodes by measuring remanent magnetism within the ferruginous components of Cainozoic weathered profiles. The timing of weathering is established by comparing the pole positions, indicated by remanence directions, with the polar wander curve established by McElhinny and others (1974) from a study of Cretaceous and Cainozoic volcanics of eastern Australia. The information sought when compiled with previous palaeomagnetic work by BMR and others will assist the establishment of a chronostratigraphic framework in Australia for the Late Cretaceous and Cainozoic. Hopefully this will permit correlation between weathered profiles and aid the age determination of associated sedimentary rocks. The ages are important, both in scientific and economic terms, having relevance to the study of mineral deposits associated with weathering.

During 1977 additional weathered profiles were sampled in the Canberra district (Gearys Gap Gravels) and in the Canning Basin (Broome Sandstone). However, the major effort was a traverse from Brisbane to Darwin via Alice Springs during which approximately 400 orientated specimens were obtained. Individual profile characteristics and sampling sites are too numerous to be listed here, but include: (a) weathered profiles, laterite profiles and ferricretes developed on Tertiary volcanics in the Brisbane/Toowoomba region; (b) weathered profiles similar to the Morney and Canaway Profiles, from the Surat, Eromanga, and Georgina Basins; and (c) laterite profiles and ferricretes preserved across parts of the Arunta Complex of the Northern Territory and in Cainozoic sediments which occupy basins within this Complex. Presumed Early and Middle Tertiary laterites of the Darwin region were sampled at Port Darwin, Bathurst Island, Melville Island, and Cobourg Peninsula.

This project is a continuation of similar investigations carried out in the Eromanga Basin where Maastrichtian/Eocene (Morney profile) and Late Oligocene/Miocene (Canaway profile) weathering events are recognised.

This study conclusively demonstrated that deep chemical weathering, as distinct from surface crusting, belongs to separate weathering episodes. The results of this investigation are to be published in Palaeogeography, Palaeoclimatology, Palaeoecology.

HYDROGEOLOGICAL STUDIES

GREAT ARTESIAN BASIN

by

G.E. Seidel

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

The Great Artesian Basin project consists of a study of the hydrogeology of the basin and development of a mathematical computer-based model to simulate the groundwater hydrodynamics. It is planned to use the model as a predictive tool in evaluating alternative management schemes for the basin's groundwater resources.

From 1972 to 1976 data were transcribed from original records held by state authorities and BMR and were stored on a computer-based data bank. A group of computer programs was developed jointly referred to as GABHYD, which are used to generate the initial data base, to calibrate the model using a newly developed direct method, run the model over an historical or future period with different management options, and tabulate and plot the results.

During 1977

- The GABHYD model was further expanded
- The model was calibrated in its entirety
- Sample applications were run to test the model's suitability as a prediction tool.
- Documentation continued of the hydrogeology of the GAB and of the GABHYD computer programs.

GABHYD programs expansion

A new program was added to the calibration group of programs to allow adjustment to potentials and calculation of transmissivities to proceed simultaneously. The necessity for this became evident at the beginning of the main phase of the calibration, when it was discovered that some recorded values of potentials were in error or required a greater geometrical detail than was available with the model. The presentation of results was improved by adding a number of output programs extracting time-dependent data to tabulate and plot them against time if required.

Model calibration

The procedure adopted for the calibration was as follows:

1) Scale transmissivities and vertical permeabilities to balance the overall water budget;
2) Determine storage coefficients from changes in water budget and drop in potentials;
3) Simultaneously calculate detailed transmissivities and adjust potentials;
4) Apply residual adjustments to vertical permeabilities.

The sequence above was applied twice because some data errors were discovered during the first pass, requiring correction and a second pass. A least-squares error criterion of the point-by-point water balances was used to monitor the progress of the calibration.

Sample applications

The first model application was a straight extrapolation from 1971 to 1999 without management intervention. The second application introduced a management intervention for 1980 in Queensland, and the third for the same year in South Australia. As expected the first run proved the basin to be near equilibrium with little changes experienced up to 1999.

The second showed the gradual recovery of potentials and the change in yields following elevation of bore outflow levels near Charleville in Queensland, and the third showed the development of a complex cone of depression resulting from a postulated new bore field near Lake Gregory in SA. Results were broadly as expected but they offered details which could not have been obtained without the model.

Documentation

The draft was completed of the report Hydrogeology of the Great Artesian Basin. The original partial draft for the model calibration documentation was completely revised following modifications to the calibration method. The remaining sections of that documentation are almost complete.

During July the project staff attended an Australian Water Resources Council seminar on groundwater modelling held at the University of NSW. Results of this study were presented and discussed at that seminar.

WIRELINE LOGGING OF WATER WELLS IN THE GREAT ARTESIAN BASIN

by

M.A. Habermehl

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

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

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

Chemical analyses of water samples from wells were added, together with barometric data used to determine ground elevations of well sites.

Drillers' logs, including rock descriptions and water levels recorded during drilling, and some technical data were added to the geophysical logs.

Basic well and log data of water wells logged by the Geological Surveys of New South Wales and South Australia in their parts of the Great Artesian Basin were also recorded.

PHOTOGEOLOGY AND REMOTE SENSING

by

C.J. Simpson

STAFF: C.J. Simpson, C. Maffi (to 11.5.77), W.J. Perry (part-time)

BMR FIELD RESEARCH

The ongoing program of regional photo-interpretation, to assist field personnel in the planning and execution of their research, involved the following BMR projects (more detailed results appear under individual project reports):

Georgina Basin project

Colour airphotos of Adam and the northeast quadrant of Mount Barrington 1:100 000 Sheet areas supplemented by black and white (RC9) photography of the Precambrian rocks (east of the Hay River) on the south-western margin of the Georgina Basin were studied. Photogeology concentrated on the delineation of the Grant Bluff Formation and the Field River Beds. Using existing field data the Field River Beds were subdivided into five major units dominantly of tillite, arkose, and dolomite. Several new major faults were interpreted and subsequently verified by field work. The existence of low-angle thrust faulting was established. Simpson joined the field party for the duration of the field activities.

Pine Creek Geosyncline project

Colour airphotos of the McKinlay River and the southern quarter of Mundogie 1:100 000 Sheet areas were interpreted. Owing to the combined effects of weathering and vegetation cover the Pine Creek region

is particularly difficult to photo-interpret, and prior field experience in the region is necessary before photo-interpretation is undertaken. Close liaison was maintained with the project, and Maffi convened the "Remote Sensing" panel discussion at the Pine Creek Geosyncline Workshop (5 May).

Detailed photo-interpretation was combined with airborne magnetic data to try to select the best positions for ground traverses to determine the sources of magnetic anomalies in the vicinity of the Burnside Granite, McKinlay River, and the Golden Dyke prospect. Field investigations by Geophysical Branch were in progress at the end of the reporting period.

Duchess project

Photo-interpretation of colour airphotos of the Dajarra 1:100 000 Sheet was carried out by W.J. Perry (Group Supervisor) who also assisted the party with field work during August-September. The photo-interpretation enabled both ground and helicopter traverses to be positioned so as to gain the maximum amount of information available.

Mount Isa-Cloncurry project

Photo-interpretation applied to problems of the subdivision and distribution of parts of the Corella Formation to the east and south of Cloncurry led to a better appreciation of its stratigraphy and structure.

REMOTE SENSING

Normanton Flood project

This project reported in 1976 was finalised by the preparation of two albums containing the main photographs acquired over the flooded region. The albums are held by BMR library.

CSIRO multiband photography

An assessment was made of the value to geological mapping of high-altitude multiband photography of the Mount Isa area obtained in 1972 by the CSIRO Division of Mineral Physics. In the area examined the multi-

band photographs provided little geological information and were less useful to geological interpretation than RC9 photographs at approximately the same scale. The reasons are: poor resolution, low contrast, relief flattening in the stereoscopic model and the fact that no feature related to geology could be emphasised by the multiband approach. A report on the assessment was published in the Bulletin of the Remote Sensing Association of Australia.

Landsat

The group continued to provide advice and arrange supply of Landsat products for other members of staff. In conjunction with the ADP Group, facilities are being developed to allow research into the computer manipulation of Landsat magnetic tape data.

Maffi and Perry evaluated Landsat research pictures prepared by CSIRO Division of Mineral Physics. Artificial parallax proportional to grey tone was introduced so that when two modified images are viewed sterescopically, a three dimensional model is seen in which dark features (i.e. those with low reflectivity) appear at low elevations, and light toned features appear relatively high. They concluded that such pictures may have benefits for some lineament studies, but are generally of no value for general interpretation of other geological structures or of landforms.

Group personnel were involved intermittently in the interdepartmental ACERTS committee organised by the Department of Science.

In response to a request to BMR by the Director of the Australian Mineral Foundation, W.J. Perry prepared an outline of a workshop course on "Geological Applications of Landsat Imagery" which will be held in Canberra under the auspices of the AMF, in November-December 1978. Contributors will include C.J. Simpson, BMR; 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 Loxton Hunting and Associates.

Skylab

The 1973 Skylab S190B stereoscopic colour photography was applied to mapping the Cainozoic deposits and Pertnjara Group outcrops in the

sand plain south of Alice Springs. Despite the small scale (1:470 000) of the positive transparencies used the space colour photography provided more geological data than could be interpreted from conventional (1:50 000 and 1:80 000) black and white airphotos of the same area. The interpreted data were added to the Alice Springs 1:100 000 scale geological Sheet.

TRAINING

An in-house refresher course in photogeology for 12 geologists was conducted from 28 February to 4 March.

Three geologists from the Geological Survey of Indonesia who are seconded to the geological mapping of Irian Jaya were instructed in photogeological interpretation techniques.

Three field party draftsmen from the Preliminary Map Compilation Group were instructed in basic photogeological techniques before they commenced field duties.

OTHER ACTIVITIES

The group continued to provide displays and instruction on photogeology and remote sensing. Delegations from Russia, China, Japan, the Australian National University, the Canberra College of Advanced Education, and the International Training Course on Mineral Exploration visited the group.

C.J. Simpson presented a paper on the use of colour photography by BMR at a Symposium on Colour Aerial Photography in Sydney on 21 April sponsored by the Remote Sensing Association of Australia. He attended a symposium (Pecora III) sponsored by the AAPG in co-operation with the USGS and NASA on the Application of Satellite Data to Petroleum and Mineral Exploration at Sioux Falls, South Dakota, from 30 October to 2 November.

The I^2S Multispectral Viewer was used by personnel from BMR and other organisations, both governmental and private.

MARINE GEOLOGY AND COASTAL STUDIES

CO-OPERATIVE PROJECTS WITH THE FEDERAL REPUBLIC OF GERMANY ON RV VALDIVIA

by

N.F. Exon

BMR participated in three research cruises on RV Valdivia during 1977 in collaboration with Government and University scientists from the Federal Republic of Germany. These projects were the first in the marine earth science field to be carried out under the Australian/German Science Agreement; the high quality of data recovered so far, and the good co-operation achieved, augur well for the future of the Agreement.

Cruise 1 (February 1977) was a short geophysical survey of the Scott Plateau, the eastern Argo Abyssal Plain, and the eastern Java Trench. Cyclones hampered activities, but 1700 km of digital seismic data, and 2550 km of gravity, magnetic and bathymetric data were recorded. These data complement those gathered by BMR, Shell, and Woods Hole, and should lead to a considerably improved understanding of the structure and geological history of the area. An excellent tie with DSDP Site 261 was obtained.

The quality of the seismic, gravity and magnetic data was generally very good, although seismic quality did suffer at the height of one cyclone. The seismic data are to be processed in Germany, and the magnetic and gravity data in Australia.

Cruise 1B (February-March 1977) was a sampling cruise on which 41 stations were attempted, 30 successfully. Cyclone Karen prevented work on the southern Scott Plateau, and forced Valdivia to spend one day working in the Java Trench. Dredge and boomerang corer stations predominated. On Scott Plateau the pre-breakup sequence was dredged in three areas and at 6 stations, and proved to consist largely of basalt, tuff and agglomerate. Regional considerations suggest that this is a rift valley sequence of Triassic and Jurassic age. The post-breakup sequence consisted of bioturbated Jurassic-Cretaceous siltstones laid down in a restricted marine

environment. They contain a sparse molluscan fauna (including ammonites) and plant remains. One chalk sample may be of Late Cretaceous age. The Tertiary sediments consisted of grey mudstone, containing some foraminifera. On the south side of the Java Trench the sediments are monotonous grey mudstones, believed to range from Late Jurassic to Tertiary in age.

Ferromanganese oxide crusts were found to be widely developed on the Scott Plateau, and nodules were recovered at one station in 2300 m of water. Subsequent chemical analyses showed the low to very low copper and nickel values, and relatively high cobalt, typical of manganese nodules from similar water depths in other parts of the world.

The third cruise took place in the Sulu Sea in May-June 1977 and had as its main objective the study of the seafloor sediments in this little-known region. Previous data suggested that the deep water body in the Sulu Sea basin is isolated from oceanic waters and of unusually high temperature (10-11^{o}C). Restricted circulation anoxic conditions were to be expected on the sea floor. The observations made from Valdivia confirm previous temperature and salinity data, but it was found that enough mixing between surface waters and deep waters takes place to preclude the formation of completely anoxic conditions at the bottom. The bottom sediments themselves have a brown oxidised surface layer a millimeter or so in thickness, but have strongly reducing conditions at depth.

Grab samples, gravity cores (5.75 m barrel), box cores (up to 17.25 m barrel), and free-fall cores were collected. Work on the sediments is continuing in Australia and at Kiel University, where N.F. Exon was on a study visit from September to November 1977.

CONTINENTAL SHELF OF SOUTHERN QUEENSLAND AND NORTHERN NEW SOUTH WALES

by

J.F. Marshall

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.

The morphology, structure, and distribution, composition and geochemistry of the superficial sediments between latitudes 25^{o} and 32^{o}S have been studied. The inner and mid-shelf regions are relatively flat; the only areas which show topographic relief are some parts of the inner shelf where bedrock is exposed, scattered low shell banks on the mid-shelf, and

wide shallow channels which run parallel to the coastline. The outer shelf is present seawards of a prominent 105 m terrace or nick point. It forms a gently sloping, slightly convex surface with a gradient of up to 6^{o}. The depth of the shelf break is variable, ranging from 145 to 440 m. Variations in the depth of the shelf break are related to topographic variations in the underlying basement surface. The upper continental slope is relatively steep with gradients from 7^{o} to 25^{o}. Numerous submarine canyons have incised the continental slope, but they do not extend onto the shelf.

Shallow seismic reflection profiling has revealed that only a thin sequence of sediments is present below the inner and mid shelf, as well as on certain parts of the outer shelf. These sediments have been deposited upon a pronounced erosional unconformity (S_2) that forms an offshore extension of the mainland geology. A sudden change of slope of the S_2 horizon beneath the present shelf break indicates that the position and depth of the shelf break is controlled by the underlying structure. Reflections above S_2 show foreset bedding beneath the outer shelf which in places has been truncated by an erosional unconformity(S_1). It is considered that S_2 represents the break-up unconformity of the western margin of the northern Tasman Basin. The steeply dipping S_2 surface beneath the continental slope possibly represents the western boundary fault of the initial rift valley.

Sands are predominant over the entire shelf, and mud is absent or only a minor component of the sediments. The amount of gravel, largely biogenic, is high in some places, but it has a scattered distribution. The amount of carbonate in the sediments increases away from the shoreline, and highest values are present on the outer shelf. In places the amount of carbonate on the outer shelf is relatively low as a result of the formation of authigenic minerals. The amount and type of carbonate material have a substantial bearing on the grainsize and sorting of the sediments. The terrigenous component of the sediments is dominated by quartz, and there are usually only minor amounts of feldspar and rock fragments. Four types of quartz grains have been identified on the basis of roundness, sorting and grainsize. These quartz types are believed to be related to various sources including beach and fluvial deposits. Skeletal carbonate components include mainly foraminifera, molluscs, bryozoa, echinoderms and calcareous red algae. Intraclasts with either a micrite or sparite cement are common

while various types of carbonate cements have developed, predominantly within the chambers of organisms. Authigenic components of the shelf sediments consist of glauconite, goethite and apatite. These are most abundant on the outer shelf, especially between 29° and 32°S. Goethite and glauconite most commonly fill the chambers of organisms, especially foraminifera, while apatite is present within the matrix of nodules and boulders of cemented nodules. The majority of the sediments on the shelf are considered to be relict.

Sediments were analysed for iron, arsenic, phosphorus, and titanium. High iron values, up to 25 percent Fe, are present on the outer shelf between 29° and 32°S. These high values are related to sediments which have high concentrations of goethite and glauconite. High arsenic values (up to 260 ppm) are associated with these sediments, and also with the phosphorites. Phosphorus values of about 6-10 percent P_2O_5 are present in nodules from the same area. Most titanium values are less than 0.5 percent Ti. Factor analysis indicates a good correlation between Fe, As and P_2O_5. The iron-rich sediments on the outer shelf are considered to have formed by the oxidation of glauconite resulting in the formation of hydrated iron oxide. Arsenic and to some extent phosphorus have been adsorbed onto the hydrated iron oxide. The phosphorites are considered to have formed as a result of replacement of micritic carbonate by microcrystalline carbonate apatite (collophane).

CONTINENTAL SHELF OF EASTERN BASS STRAIT AND EASTERN TASMANIA

by

Peter 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.

The morphology, structure, sediment distribution and geochemistry of the shelf between Gabo Island and southern Tasmania are being studied. A prominent break of slope at a depth of between 50 m and 90 m divides the shelf into inner and outer parts. Terraces are most prominent between 110 and 113 m and between 30 and 140 m. On the upper continental slope they occur predominantly between 190 and 220 m. The shelf break ranges in

depth from 124 to 179 m. It is shallowest in the area of the Bass and Maria Canyons, and is deepest along the southern margin of the Tasmanian shelf.

Seismic studies show a likely pre-Tertiary basement surface beneath the shelf off eastern Tasmania. It everywhere slopes eastwards away from the land, and exhibits a marked increase in slope in the mid-shelf area where it is frequently stepped. The sediment sequence above basement exceeds 400 m in thickness over most of the shelf. Basement is not visible in the subsurface of eastern Bass Strait. Subsurface reflectors in the area of the shelf break are interpreted as disconformities representing palaeo-shelf surfaces and palaeo-shelf breaks having an origin attributable to marine erosional processes associated with lower sea levels.

Four sediment facies are recognised on the shelf:1. inshore quartz-rich sands; 2. crushed foram/bryozoa with some quartz; 3. coarse mollusc/bryozoa sands; and 4. outer shelf coarse quartz sands. The coarsest sediments occupy the inner and outer shelf, while the middle shelf is dominated by fine to very fine sands. Calcium carbonate increases away from the shoreline. Highest values occur on the southern Tasmanian shelf.

MANGANESE NODULE FIELD OFF SOUTHWESTERN AUSTRALIA

by

H.A. Jones

In July-August 1977 BMR undertook further dredging for deepsea manganese nodules off Western Australia in the Royal Australian Navy frigate HMAS Diamantina.

The existence of an extensive manganese nodule field southwest of Cape Leeuwin, WA, was first indicated by bottom photographs taken from the research vessel USNS Eltanin in 1970. Samples from the deposit were dredged by a joint BMR-Monash University team in Diamantina in January-February 1976, and the results of the analysis of this material were published by Frakes, Exon & Granath in the BMR Journal in 1977. The average combined nickel plus copper plus cobalt values from all stations was 1.53 percent, and the range 1.27 percent to 1.76 percent.

The objective of the 1977 cruise in Diamantina was to collect more material for analysis, particularly from the eastern part of the field

where there is reason to believe that higher nickel and copper values are found than to the west. Scientists from Monash University collaborated in the work.

HMAS Diamantina is a frigate of 1340 tons displacement converted for oceanographic research in 1969. She was fitted with satellite navigation during the 1977 survey, whereas in 1976 she had to rely on positioning by conventional celestial navigation. Malfunctions of the echo-sounder, however, caused difficulties during dredging and necessitated minor adjustment to the planned dredging sites in order to position the stations on soundings charted on the 1:1 million GEBCO Sheets. Recorded water depths are therefore approximate.

Eleven deepwater dredging stations were occupied during the cruise; seafloor material was recovered at 9 stations, 7 of which yielded nodules and one recovered rock fragments encrusted with ferromanganese oxides. Station data are listed in Table S2. Chemical analyses are not available at the time of writing. The location of the stations is shown in Fig. S8.

Although disadvantaged by the failure of the echo-sounder, and by bad weather towards the end of the cruise, useful additional information on the extent of the Cape Leeuwin nodule field was gained. Nodules were recovered at the farthest east station occupied (118°E), but their concentrations on the sea floor here is possibly low. The largest haul of nodules was recovered close to the southern flank of the Diamantina Fracture Zone (Stn 5); the presence of thick encrustations of Fe and Mn oxides on rock fragments north of the Fracture Zone less than 200 miles from continental Australia suggests that further exploration of areas adjacent to the continental margin in this region is warranted if high trace metal values are recorded.

The nodules recovered are typical in size and shape of others previously collected from this field. Many have a relatively abundant and varied encrusting fauna of agglutinating foraminifera. The great range in thickness of manganiferous crust (1 mm - 4 cm) on rocks dredged at Station 11 is somewhat puzzling and suggests erosive-strength bottom currents may operate in this area.

TABLE S2 MANGANESE NODULE SAMPLING STATION DATA

Station	Position	Water depth (m)	Nodule diameter (cm)	Sample description
1	38°30'S 118°03'S	5300?	-	No recovery
2	39°56'S 118°00'E	4700	2-6	7 nodules and red clay
3	39°58'S 115°56'E	4750	1-1.5	3 nodules and red clay
4	38°09'S 115°57'E	4050	-	Red clay
5	38°38'S 114°00'E	4650	4-7	25 kg of sub-spherical well-sorted nodules and red clay.
6	38°33'S 111°59'E	4600	2-6	12 kg of nodules poorly sorted and irregular in shape. With red clay.
7	40°00'S 112°01'E	4200	2-5	15 kg of nodules. Mostly small and somewhat irregular in shape. With red clay.
8	41°00'S 112°02'E	4500	0.5-1.5	3 small nodules and an encrusted shark's tooth (6 cm). With red clay.

TABLE S2 (Continued)

Station	Position	Water depth (m)	Nodule diameter (cm)	Sample description
9	40°02'S 110°04'E	4600	2.5-6	13 nodules and red clay.
10	38°30'S 110°00'E	-	-	No recovery
11	36°38'S 112°16'E	4100	-	25 kg of rock fragments up to boulder size heavily encrusted with manganese and iron oxides.

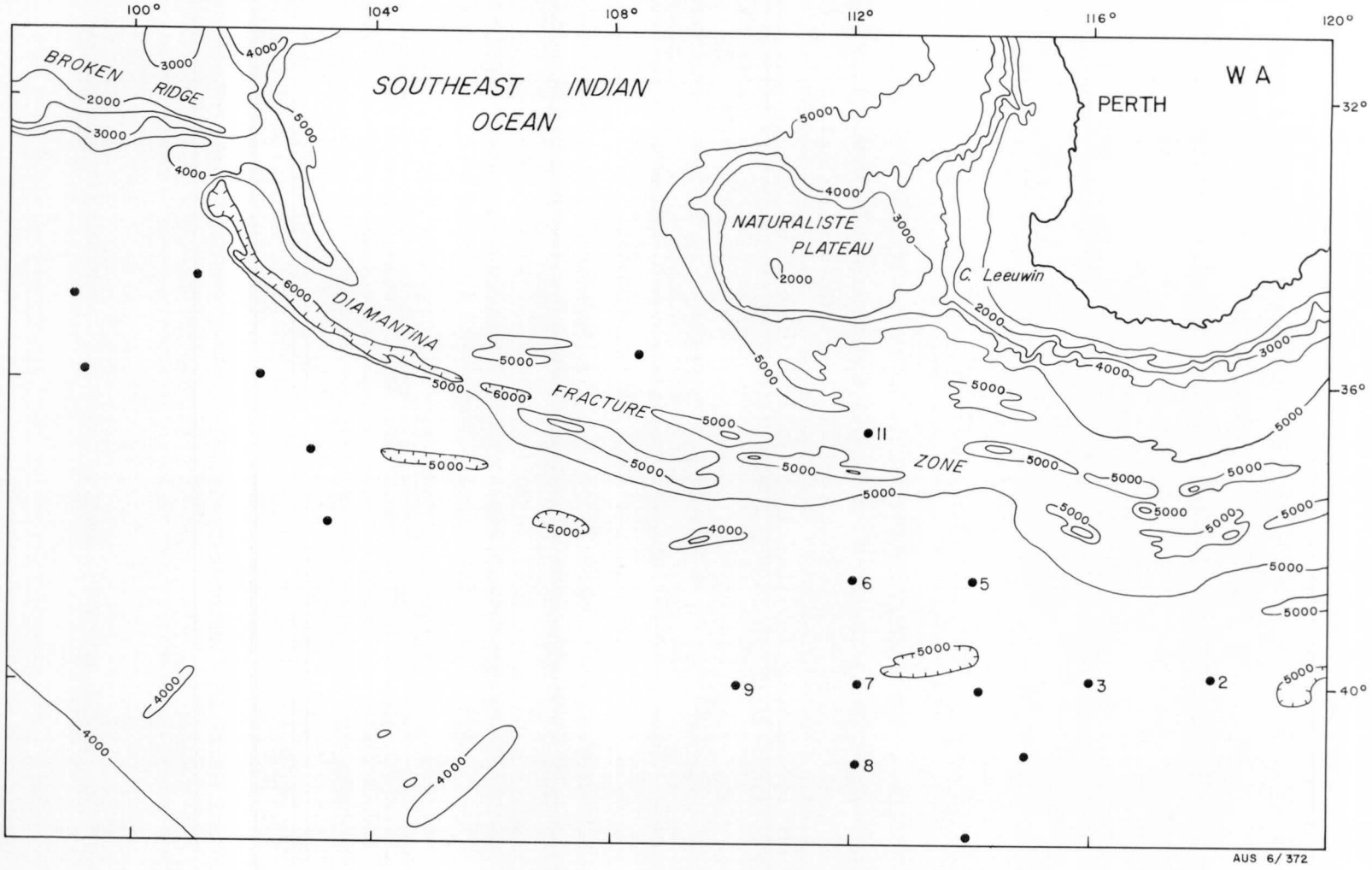


FIG.S8 Dredge stations at which manganese nodules and crusts have been recovered. Numbered sites refer to the Diamantina 1977 cruise.

Previous analytical data on nodules from this field indicate nickel and copper values somewhat higher than average for the Indian Ocean; however, these values are still significantly lower than those from the areas in the eastern Pacific where mining is in prospect.

COASTAL STUDIES IN SOUTHEAST SOUTH AUSTRALIA AND WESTERN VICTORIA

by

J.B. Colwell

Studies of the stratigraphy and sedimentology of the Late Cainozoic sequence of southeastern South Australia continued during the year. The project, which had involved extensive stratigraphic drilling in 1974 and 1975, aims to provide stratigraphic and sedimentological information on the regressive coastal sequence and to use this information to define Pleistocene sea-level changes. Details of the stratigraphy were published in the BMR Journal during the year. Results of heavy mineral studies were written-up and indicate generally unfavourable conditions for the occurrence of significant heavy mineral accumulations in the largely calcareous sediments of the region. A detailed investigation of the mineralogy of the sediments using X-ray diffraction was completed. Quartz, calcite and minor feldspar constitute most of the beach and dune deposits. Calcite, dolomite, quartz and minor aragonite occur in various combinations in the interdune sequences.

The major part of the work undertaken during the year involved extending the southeast South Australian investigation into the adjacent area of central western Victoria where older, more siliceous strandline ridges occur. Ten holes ranging in depth from 45 to 101 m were completed in the Edenhope and Nhill-Kaniva areas during February and March (Fig. S9). The holes intersected a number of major units including the Woorinen and Coonambidgal Formations (Quaternary), the Parilla Sand (Pliocene), and the Bookpurnong Beds (Pliocene) (Fig. S10). As a result of continuous coring

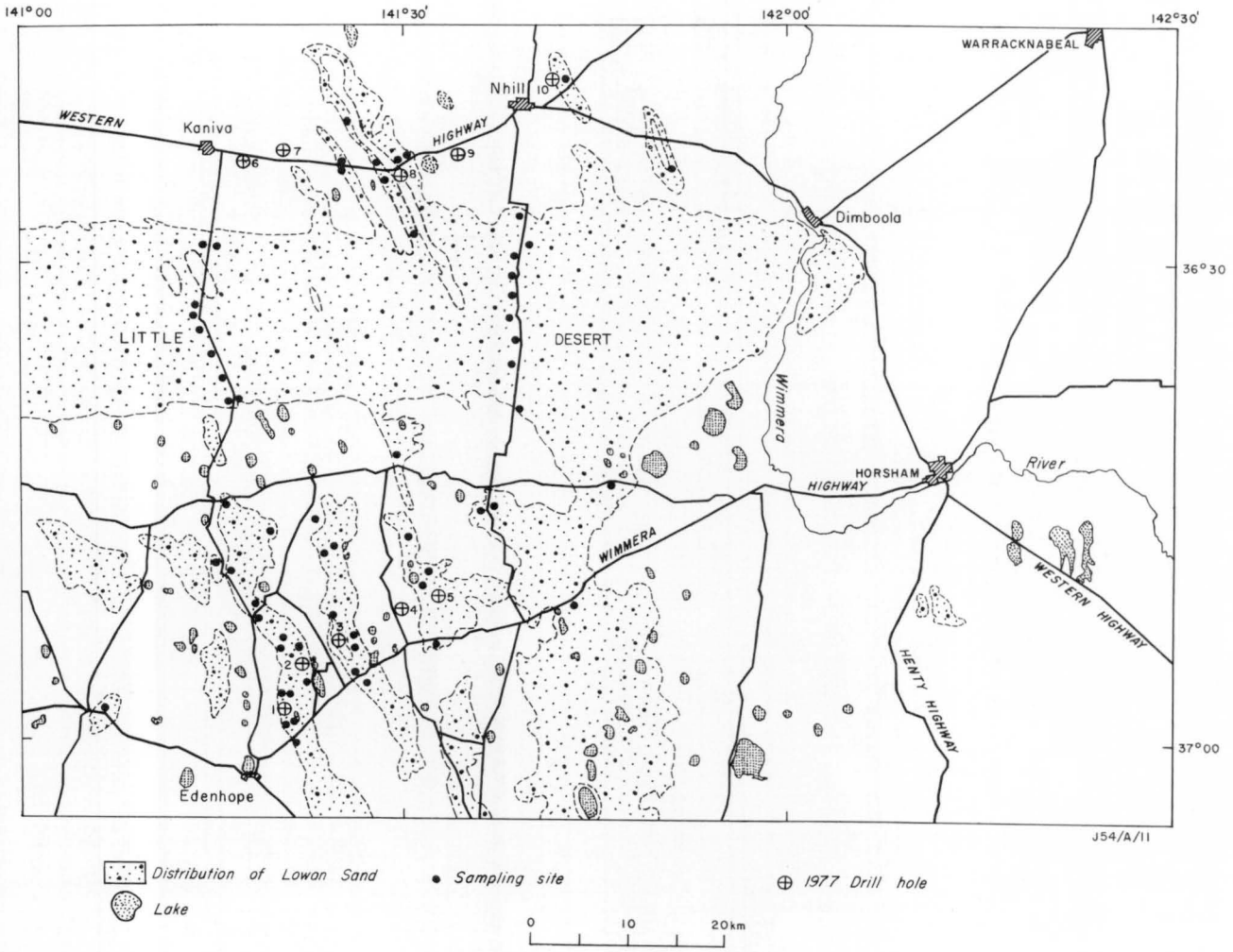


FIG.S9 Distribution and location of sampling sites of the Lowan Sand

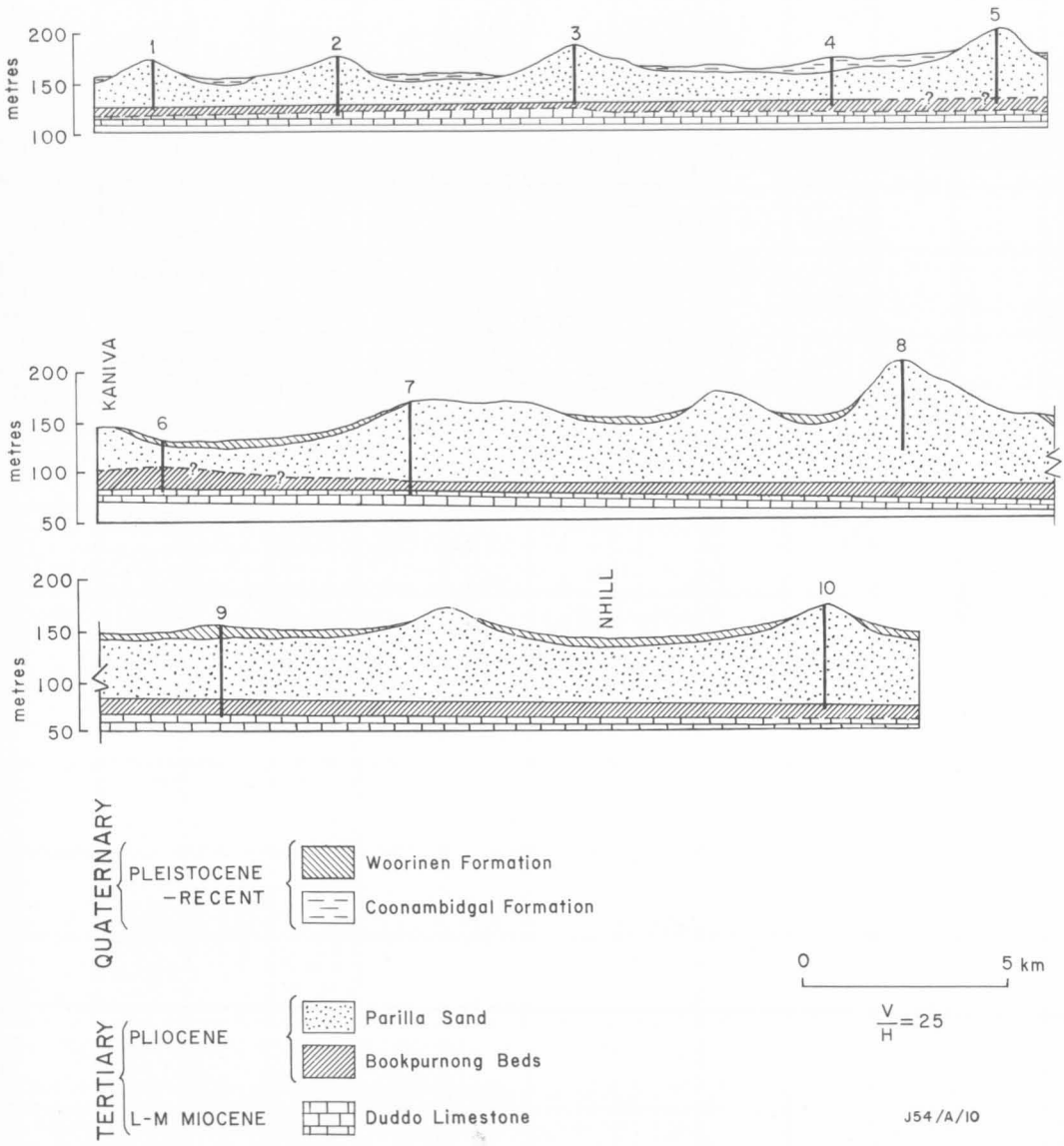


FIG.S10 Cross sections showing the major late Cainozoic units

detailed stratigraphic information was obtained from virtually the entire sequence. Samples were selected for sedimentological, palaeontological and other studies.

The Parilla Sand which comprises most of the Late Cainozoic sequence in central western Victoria, has been studied in detail. It forms the strandline ridges of the region and consists of a series of quartz sands with minor silt, clay and gravel components. The sands in the upper (dune) part of the unit in the ridges are predominantly medium or medium to fine-grained, moderately well sorted and fine skewed. In general these are underlain by a series of similar but less uniform sands (typical beach deposits) containing thin layers of quartz gravel in their lower parts. In the Edenhope area these are in turn underlain by a series of fine to very fine-grained, well sorted, fine skewed sands of probable shallow marine or estuarine origin. In all cases the sands are devoid of carbonate. Heavy mineral concentrations are generally moderately low (usually less than 0.5 percent), although in the lower (beach) part of the sequence, laminae and thin bands of concentrated heavy mineral occur in holes 5, 6, 7 and 9. The sediments containing the higher heavy mineral concentrations generally average between 3 and 5 percent total heavies. Individual bands (usually 1 to 2 cm thick) contain up to 18 percent total heavies. The suite is mineralogically mature and consists of between 50 and 70 percent opaques (mainly leucoxene and ilmenite), 10 to 30 percent tourmaline, 3 to 5 percent rutile and 5 to 15 percent zircon. Many of the grains are well rounded and are probably derived from multicyclic sources.

THE FORMATION OF BAHAMIAN OOIDS

by

P.J. Davies, B. Bubela and J. Ferguson

Experimental work on the organic and inorganic factors operative in ooid formation has been carried out in conjunction with the Baas Becking Laboratory, the objective being to determine the environmental conditions in which they form, and to apply this information in interpreting the fossil record. Bahamian type ooids, exhibiting a tangential orientation of crystal laths, have been synthesised under conditions of agitation, super-saturation and without the intervention of organic processes during the

precipitation. Complete growth is divided into agitation, resting and sleeping stages. In the agitation stage, quartz nuclei induce an inorganic, heterogeneous nucleation from a supersaturated solution, which finally cease as a result of Mg^{2+} and possibly H^{+} poisoning of the carbonate surfaces. No further precipitation occurs until the crystal surfaces are reactivated by removal of Mg^{2+} and H^{+} during the resting stages. Following a series of agitation and resting stages, precipitation is inhibited by a degree of poisoning which is not totally removed during the resting stage. For further growth to occur, a new substrate is required and is provided by the development of organic membranes around the grains. Such membranes develop while the grain is at rest in the subsurface, the period of organic growth constituting the sleeping phase.

Analysis of the organic components of Bahamian ooids shows compounds capable of membrane formation in the manner indicated by the laboratory studies.

GREAT BARRIER REEF STUDIES

by

P.J. Davies and J. F. Marshall

During April 1977, the reefs of the southern Great Barrier Reef were studied by P.J. Davies, J.F. Marshall, J. Kennard and D. Foulstone (BMR), H. Heckel, D. Searle and I. Heath (Geological Survey of Queensland) and Professor B. Thom (University of NSW). The objectives were:

1. High-resolution boomer surveys of inter-reefal areas.
2. Seismic refraction surveys of the reefs.
3. Scuba exploration of windward and leeward edges of reefs.

The MV Sea Hunt was chartered from Gladstone. Extensive boomer coverage was obtained only from the area of the Capricorn Reefs. Results indicate that unconformities identified in the Heron Island borehole may be traced between the reefs, and crop out in numerous places. The inter-reefal areas are therefore floored by Pleistocene rocks eroded during the Wisconsin sea level low, and mantled with a thin veneer of sediment.

The Holocene reefs are not as extensively developed at present compared to the distribution of the Pleistocene reefs.

Seismic refraction studies on the reefs of the southern Great Barrier Reef show a major seismic disconformity at depths between 7.3 and 19.1 m, this representing the contact between the Holocene reef and its pre-Holocene substrate. Depth variations are often large beneath individual reefs (3-12 m). The disconformity is shallow around perimeter margins, and often shallowest on the windward margins. Patch reefs within lagoons also occupy elevated sites, while lagoons correspond with depressed parts of the disconformity. The shape and depth of the pre-Holocene surface therefore reflect present-day reef shape.

Bathymetric and scuba studies show reefs occupying positive areas rising abruptly from a uniform depth of 60 m. Indurated cliffs are characteristic of windward margins, while leeward sides are shallower and gentler and are generally the sites of extensive sand sheets interspersed with actively growing reef pinnacles. This accords with observations of dominant water movements across the reefs from windward to leeward.

Reef shape is time-dependent, in the sense that "young" reefs at a stillstand sea level exhibit strong substrate control over plan shape and sectional geometry. However, as they age at a stillstand sea level, the effects of substrate morphology will become masked by hydrodynamic factors.

PALAEONTOLOGICAL STUDIES (Fig. S11)

J.M. Dickins

J.M. Dickins attended the 4th International Gondwana Symposium held in Calcutta 17-22 January. The meeting was sponsored by the Subcommission on Gondwana Stratigraphy of IUGS, of which he is the chairman, and the Geological Survey of India. Outstanding features of the meeting were the work on Himalayan geology and the correlation of the Gondwana areas with other parts of the world. He delivered a key paper, now published, on the relation between Indian and Australian Permian faunas, from which it can be concluded that Peninsular and Himalayan India were in juxtaposition in the Permian. After the meeting he visited the Raniganj and Jharia Basins (the main coal-producing areas of India), the Geological Survey of India Training Institute, and GSI Laboratories at Lucknow.

February and part of March was spent in Europe working on Upper Palaeozoic fossil collections at the British Museum (Natural History), London, and in Scotland and Holland, during leave.

In Canberra he completed a draft report on the Permian marine invertebrate fauna from the Warwick area, Queensland. This fauna is significant for the time relationship and the climate of the eastern Australian Permian sequences.

Through the Permian and Gondwana Subcommissions collaboration is being organised to improve the Permian time scale.

M. Plane

Cainozoic mammalian remains are being studied with the aims of establishing their age and environmental implications as an aid to correlation.

Work continued on fossil faunas from Bullock Creek, Northern Territory; Riversleigh, Queensland; and Lake Palankarinna, Pinpa and Ngapakaldi, South Australia.

Field work at Lake Palankarinna produced new small fossil mammals from beds stratigraphically higher and lower than those previously known, and new sites were found at Lake Kanunka and Pitikanta. This work was undertaken jointly with the Queensland and South Australian Museums. Further field work in conjunction with the School of Biological Sciences, Flinders University, produced new mammal locations in Tertiary limestone on Deep Well Station just south of Alice Springs.

A training scheme in Palaeontology laboratory techniques was initiated for trainee technical officers.

S.K. Skwarko

S.K. Skwarko completed four additional papers on the Mesozoic molluscs of Papua New Guinea and Australia; these together with papers written earlier will probably be published as a bulletin.

He identified and dated belemnites and bivalves from the Sula Islands, Indonesia, and prepared a preliminary report for later publication. He also contributed to, and edited, a joint paper on the Jurassic biostratigraphy of the Sula Islands. The Sula Islands Middle and Late Jurassic

1 Eocene nannofossils, Ninetyeast Ridge
2 Oligocene and Miocene larger and planktonic foraminifera
3 Upper Cretaceous-Eocene nannofossil biostratigraphy
4 Palaeozoic conodonts, Carnarvon Basin
5 Santonian, Palaeocene & M.Eocene nannofossils
6 Eocene nannofossils, Naturaliste Plateau
7 Lower Cretaceous spores, pollen and dino-flagellates from Carpentaria Basin
8 Late Cambrian trilobites, Bonaparte Gulf Basin
9 Lower Carboniferous ostracods from the Bonaparte Gulf Basin
10 Lower Carboniferous and Upper Devonian ostracods, Canning Basin
Upper Devonian and Lower Carboniferous fishes from the Canning Basin
11 Permian invertebrate faunas including ichnolites
12 Lower Ordovician Dikelokephalinidae from northern Australia
13 Upper Palaeozoic and Mesozoic plants
14 Middle Eocene nannofossils
15 Carboniferous and Lower Triassic Conchostracans, Canning Basin
16 Cambrian & Ordovician trilobites, Mootwingee area, N.S.W.
17 Precambrian stromatolites and microfossils
18 Tertiary land mammals, Deep Well, N.S.W.
19 Agnostid trilobites from N.T. and N.S.W.
Middle Cambrian trilobites of northern Australia
20 Tertiary pollen grains, Ti Tree area
21 Biostratigraphy of Upper Devonian vertebrates in Amadeus & Georgina Basins
22 Ordovician invertebrates, Wiso Basin
23 Late Cambrian trilobites (Chatsworth)
24 Late Cambrian and early Ordovician trilobites and conodonts, Georgina Basin
25 Early Devonian thelodont fish scales, Toko Range
26 Upper Permian & Lower Triassic Conchostracans Bowen Basin
27 Silicification of modern algae
28 Eocene nannofossil biostratigraphy
29 Palynology of the Ronlow Beds
30 Permian spores and pollen, Galilee Basin
31 Miocene larger foraminifera
32 Lower-Middle Miocene nannofossils
33 Lower Triassic Conchostracans, Bonaparte Gulf Basin
34 Eocene-Oligocene nannofossils, Coral Sea Basin. Oligocene-Miocene larger foraminifera, Georgina Basin.
35 Middle Cambrian bradoriids, Georgina Basin
36 Permian fauna from the Warwick area
37 Silurian conodonts, Canberra region. Silurian encrinurid trilobites of south eastern Australia. Silurian brachiopods and biostratigraphy of the Canberra region
38 Devonian fishes from eastern Australia
39 Tertiary foraminifera, PNG
40 Carboniferous spores from Ngalia Basin
41 Tertiary land mammals
42 Jurassic and Neocomian dino-flagellates. Cape York, Carpentaria Basin
43 Tertiary rodents from PNG
44 Lake Entrance shelf - Planktic Foraminifera
45 Late Cretaceous foraminifera

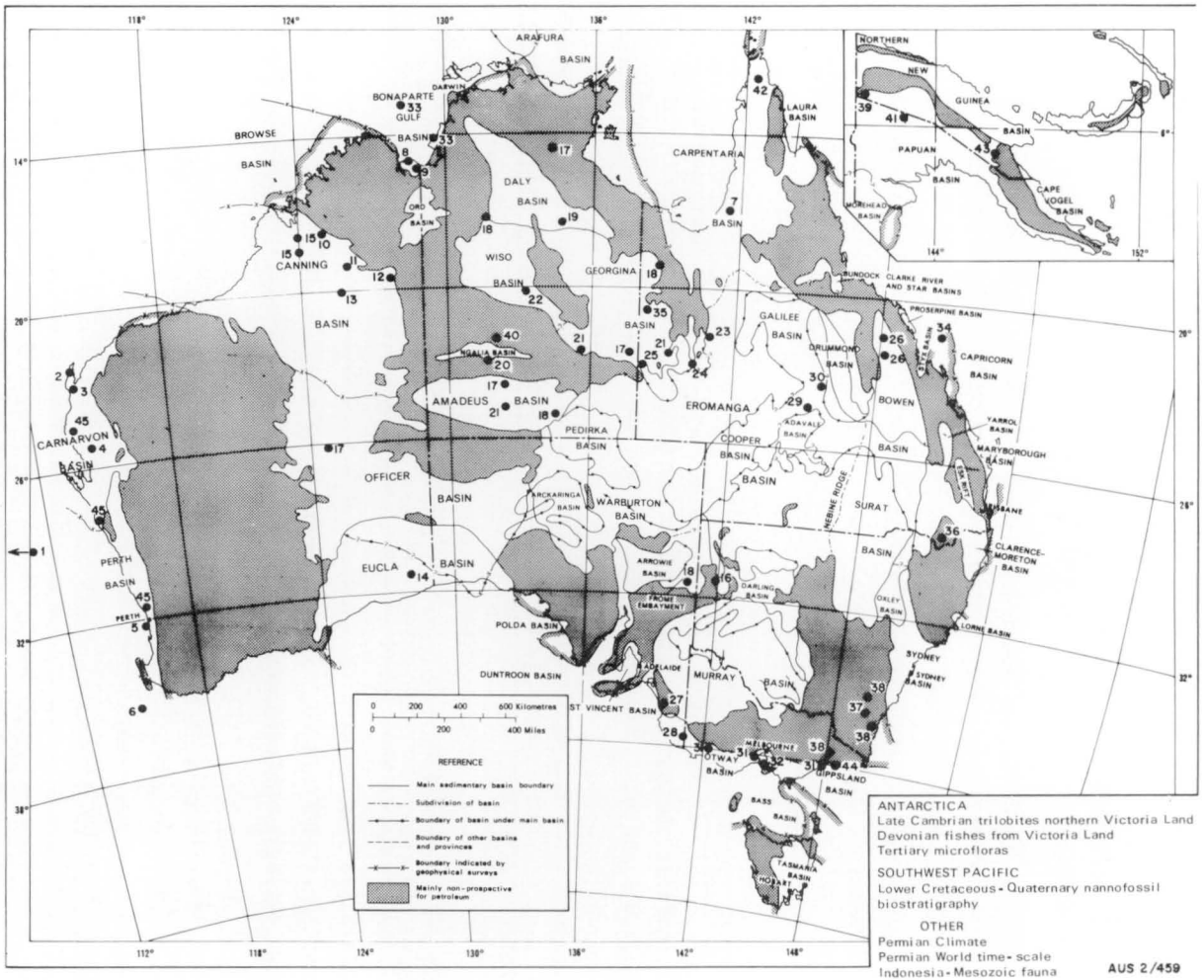


FIG. S11 Current Palaeontological Projects

sequences are particularly important, as they are a key to the intercontinental correlation between Irian Jaya, Papua New Guinea, Australia, New Caledonia, New Zealand and Antarctica on the one hand, and Southeast Asia and Indonesia on the other.

Routine duties involved Skwarko in identification and dating of fossils sent in from parts of Australia and Papua New Guinea, 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.

J.H. Shergold

J.H. Shergold completed systematic descriptions of Late Cambrian trilobites from the Chatsworth Limestone of the Chatsworth area, Burke River Structural Belt, western Queensland; and continued to work on Idamean collections from Mount Murray and sections north of Chatsworth. A review of the Lower Palaeozoic geology of the Georgina Basin was co-authored with E.C. Druce as a contribution to an Elsevier book "Lower Palaeozoic rocks of Australasia".

IGCP Project 156, Proterozoic and Cambrian Phosphorites, Asia and Australia, was initiated with P.J. Cook (ANU), and will run for 5 years. This project seeks to establish the reality of a phosphogenic province in the Australian-Asian region during Late Proterozoic to Middle Cambrian time; to establish its extent, its diagnostic sedimentological, petrological, geochemical, biological and economic characteristics, and the details of its biochronological framework.

Continuing activities include: (1) Participation in IGCP Project 7, Southwest Pacific Basement Correlation through the examination of further Late Cambrian trilobites from Victoria Land, Antarctica, in collaboration with R.A. Cooper (New Zealand Geological Survey) and J.B. Jago (South Australian Institute of Technology); (2) Collaboration with B.D. Webby (University of Sydney) on the Lower Palaeozoic stratigraphy of the Mootwingee area (western New South Wales); (3) Production of an annual Newsletter on behalf of the Early Palaeozoic Working Group of the IUGS Subcommission on Gondwana Stratigraphy; (4) Conducting the activities of the Cambrian Correlations Working Group of the IUGS Sub-

commission on Cambrian Stratigraphy; (5) Participating in the activities of the IUGS Cambrian-Ordovician boundary Working Group.

Visits were paid to Lower Palaeozoic sections along the Peel Fault, Tamworth, New South Wales, the Mootwingee area of western NSW, and the Georgina Basin. Activities with the Georgina Basin Project are listed under that project.

D.L. Strusz

D.L. Strusz is engaged in a stratigraphic 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 Geosyncline.

The stratigraphic side of this study at present involves supervision of 1:100 000 mapping projects in the Canberra area and co-operation with the Engineering Geology Group.

Palaeontological work is focused on the Silurian rocks - and thus is also a contribution to Project Ecostratigraphy, a Category A project of the IGCP. For some time to come, work will continue to be concerned with documenting Silurian faunas from the variety of horizons and palaeoenvironments, so as to build up a usable biostratigraphic framework. The first part of this work has been a study of the trilobite family Encrinuridae, a widespread group much in need of revision. A broader study of the brachiopod faunas has started with large collections of well preserved material from a small area west of Canberra, of Wenlock age (the first locality of such age in Australia for which the fauna will be well known).

Further activities have been:

1) Curatorial duties, especially curating BMR specimens used in a study of Silurian trilobites from the Yass-Canberra district by B.D.E. Chatterton (University of Edmonton) and K.S.W. Campbell (ANU);

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 for the Geological Society of Australia.

J. Gilbert-Tomlinson

The two taxonomic bulletins (BMR Bulls 171, 174), written jointly with J. Pojeta Jr (US Geological Survey) and summarising current knowledge of Australian Cambrian and Ordovician bivalved molluscs, submitted to the printer in November 1976 have reached proof stage and are expected tc be published before the end of the year. Bulletin 171 (Cambrian and Ordovician rostroconch molluscs from northern Australia, by Pojeta, Gilbert-Tomlinson, and Shergold) deals with 15 genera (6 new), and 32 species (21 new) from the Amadeus and Georgina Basins of mainland Australia. Noteworthy is the unusual wealth of rostroconchs in Australian Upper Cambrian rocks: 11 species compared with 4 in the whole of the Cambrian System elsewhere in the world. Bulletin 174 (Australian Ordovocian pelecypod molluscs, by Pojeta and Gilbert-Tomlinson) deals with one new family, 31 genera (20 new), and 47 species (27 new) of pelecypods from northern Australia and Tasmania, and 2 new species of Tasmanian Ordovocian rostroconchs, the latter supplementing the descriptions in Bulletin 171. The Bulletin presents the first major study of Ordovician pelecypods from the Southern Hemisphere; furnishes new insights into the composition of pelecypod faunas from the poorly-documented Lower Ordovician/lower Middle Ordovician part of the geological column, particularly in clastic rocks; and extends downwards the known stratigraphic ranges of several taxa.

A paper on Ordovician vertebrates from northern Australia was prepared jointly for publication in Alcheringa, with A. Ritchie, Australian Museum, Sydney, providing the taxonomy and Gilbert-Tomlinson the stratigraphy. The fossils (heterostracan ostracoderms from the Stairway Sandstone, Amadeus Basin, NT) are assigned to a new order and family and two new genera and species and are among the earliest (early Middle Ordovician) armoured vertebrates yet recorded in the world. The first material was collected by D.J. Taylor, and additional material by BMR geologists, including Gilbert-Tomlinson, who established their stratigraphic position by intensive collecting in several sections in order to determine their

temporal relationship with diagnostic invertebrates, whose succession, in turn, has been worked out after several seasons' mapping by BMR geologists throughout the Basin.

Examination of old trace fossils collections held at BMR has revealed a most remarkable accumulation of highly significant ichnolites, mostly from the Canning Basin, and mostly of Permian age. A systematic study of the collection, which includes many forms not previously recorded from the Southern Hemisphere, was undertaken.

A talk entitled "Uses and abuses of trace-fossils", was given in the BMR lecture series in Feb. 1977, and another, "Geological record of early vertebrates", was given in the Palaeontological Group's monthly series.

G.C. Young

G.C. Young completed his work on Devonian fish from Australia and Antarctica in London as part of his award of a PSB Scholarship for two years and returned to Canberra in December. A PhD was awarded for his work.

Following his return, additions were made to the Bureau collections of Palaeozoic fishes and the study of these collections was continued. The objectives of this research are to provide new information on the structure and evolution of early vertebrates through the description of poorly known Australian and Antarctic faunas, to determine the stratigraphic range of these faunas as a basis for the correlation of non-marine Devonian rocks, and to investigate the significance of their geographic distribution in the context of continent positions during the Palaeozoic.

1. Antarctic collection. Most of the antiarch material in the collection from the Aztec Siltstone (Victorialand, Antarctica) has now been prepared. During the year a new genus of antiarch was recognised, and a manuscript describing this and the several species of Bothriolepis from the fauna is in preparation and due for completion in 1978.

2. Taemas/Wee Jasper, NSW. Further material was collected from the Early Devonian limestones, and acid preparation was continued throughout the year. Other material was borrowed from the Geology Department, Australian National University, for preparation and study. A manuscript describing a new species of petalichthyid from this fauna was submitted to Alcheringa, and another manuscript giving a comprehensive account of braincase structure in Buchanosteus was completed for publication.

A Middle Devonian fish fauna was collected from a locality in the Hatchery Creek Conglomerate discovered during mapping by the Tantangara Party in 1975. A joint manuscript with J. Gorter describing this fauna is in preparation. The occurrence is of biostratigraphic importance in being the first Middle Devonian fish fauna of European aspect discovered in the Southern Hemisphere.

3. Gogo collection. Several lungfish specimens from the collection are being studied by Dr K.S.W. Campbell (Australian National University) in conjunction with his work on growth of bone and tooth structure in lungfishes. A joint paper with Dr R.S. Miles (British Museum) describing ptyctodontid placoderms from the Gogo fauna was published early in the year.

4. Central Australian collection. Six weeks were spent collecting Devonian fishes from the Cravens Peak Beds in the Georgina Basin. An abundant and diverse fauna was discovered which includes placoderms, crossopterygians, onychodontids, acanthodians and thelodonts. Detailed study of this material will commence in 1978 in conjunction with the description of other material from the Amadeus and Georgina Basins collected in 1973 and 1974.

M.E. White

Mary White continued working on fossil plants (under contract).

A.A. Opik

Dr A.A. Opik continued his work on Cambrian trilobites in association with the group.

D.J. Belford

A palaeontological data retrieval system was established in conjunction with the ADP Group, and data entry has begun. The system is being designed to produce catalogues of the palaeontological collections, and will enable the collections to be arranged in order of age, faunal content, and sedimentary basin or map area. The system will be used to catalogue all the foraminiferal collections, including the CPC Collection, and will also be used for the ESCAP Collection. It is intended to enter all current projects as work is completed; earlier collections will be added as opportunity offers. Considerable progress has been made during the year in curating the Bureau's foraminiferal collection, particularly that from Papua New Guinea, with the assistance of F. Hadzel and P.W. Davis.

Palaeontological work has been carried out for the Papua New Guinea Geological Survey and for the Irian Jaya Project; faunas examined range in age from Cretaceous to Pliocene. Systematic study of the faunas continued when possible, and a short paper describing a new foraminiferal genus Quasicyclammina from the Paleocene of Papua New Guinea has been published. In conjunction with Dr C.G. Adams of the British Museum (Natural History) another new foraminiferal genus from the Chimbu Limestone (Eocene) has been described, and the manuscript is in the final stages of preparation.

Samples collected by the RV Valdivia from the Scott Plateau were examined; most of the material was Quaternary in age, but one core regarded as Campanian in age was taken. This core contains a very well preserved fauna of planktic species; the locality is close to Site 261 of the Deep Sea Drilling Project, which yielded only benthic agglutinated foraminifera from zeolite clays. The faunal difference reflects the depth difference of sampling sites: the Valdivia sample was taken from 2000 metres, and the DSDP sample from 5667 metres, below the carbonate compensation depth.

Additions to the ESCAP Fossil Reference Collection continued through the year; preparation of a supplementary catalogue was deferred until the palaeontological data retrieval system was established. Data required for the preparation of a catalogue are now being entered into the system.

P.J. Jones

P.J. Jones continued biostratigraphic studies aimed at the refinement of the Carboniferous time scale. Activities to this end included (i) the taxonomic revision of the Lower Carboniferous Ostracoda from the Bonaparte Gulf Basin, in the light of results of a concurrent study of ostracods collected from reference sections of Lower Carboniferous (Dinantian) marine rocks in western Europe (Belgium, northern France), the USSR (Moscow Basin, and the South Urals), and the USA (Indiana); (ii) the description of Conchostraca (indicating fresh-water habitat) from the upper part of the type section of the Anderson Formation (Lower Carboniferous), Canning Basin, in a paper completed in collaboration with Professor Paul Tasch (University of Wichita, Kansas); and (iii) the critical evaluation of a MS, now published, on 'Carboniferous and Permian palynostratigraphy of Australia and Antarctica: a review' by Dr E.M. Truswell and fellow palynologists.

Two papers dealing with Conchostraca from the Lower Triassic rocks of the Canning and Bonaparte Gulf Basins were completed in collaboration with Professor Tasch, and a third paper written by the latter author on Conchostraca from the Upper Permian and Lower Triassic rocks of the Bowen Basin was edited. The three papers describe new species of Conchostraca, discuss their palaeoecological and palaeogeographical significance, and postulate possible routes for the dispersal of conchostracan eggs in fresh-water lakes from Carboniferous to Triassic time.

A check list of Ostracoda recorded from Australia and Papua New Guinea (1845-1973) was partly re-edited, and finally sent to press. This report, prepared jointly with P. de Deckker (University of Louvain, Belgium), is a bibliographical tool for workers engaged in ostracod research, and represents the Australian contribution to the International Palaeontological Association Study Group project - 'Shallow marine and freshwater Ostracoda of Tethys'.

E.M. Truswell

Palynological and associated research completed or continued during 1976/77 was concerned with both Late Palaeozoic and Tertiary intervals; these are detailed separately below:

1. Late Palaeozoic palynology. A review of the palynology of Carboniferous and Permian sequences in Australia and Antarctica was commenced in 1976, intended for presentation at the 4th International Palynological Conference in Lucknow, India, in December 1976. Attendance at the Conference was not possible, but the review was continued and expanded during 1977 to include the entire Carboniferous, rather than just the Late Carboniferous glacial interval, as originally intended. The review was published in the BMR Journal (1977, 2(3), 177-209), and authored by E.M. Kemp, B.E. Balme, R.J. Helby, R.A. Kyle, G. Playford and P.L. Price. In it, some 13 palynostratigraphic units have been recognised between the base of the Carboniferous and the top of the Permian in Western Australia, and 16 units are identified in the same interval in eastern Australia. Correlation between these independently derived schemes remains tentative, as does the relationship of the units to internationally recognised stages.

An interim report on the palynology of part of the Late Carboniferous to Permian interval in Tasmania was completed in 1977, and is now in press (Geological Survey of Tasmania, Bulletin 56). The work recognises Stages 1 and 2 of the eastern Australian palynological sequence associated with glacial deposits in a number of localities, Stage 3a in overlying marine sediments such as the Quamby Mudstone and Masseys Creek Group, and Stage 3b linked with the Mersey Coal Measures. The relationship to Tasmanian faunal zones has been established.

In mid-1977 work commenced in earnest on the palynology of the oldest part of the Late Palaeozoic sequence in the Galilee Basin of Queensland. The work has as its primary aim the description of microfloras assigned to Stages 1 and 2, and occurring in lithological units of the Joe Joe Group. The borehole GSQ Springsure 13 is being used as a taxonomic reference in the early stage of the work. Surprisingly diverse microfloral assemblages have been recovered from this glacially deposited interval. Most of the potentially valuable index species for the Stage 1 interval have been photographed with the light microscope; a program of photography using the SEM has begun. Distinctive species of Dibolisporites, Apiculatisporis and Anapiculatisporites have emerged as potentially of stratigraphic value.

From the Ngalia Basin of central Australia, rich assemblages of palynomorphs have been recovered from the Mount Eclipse Sandstone. Most of these can be assigned to the recently defined Anapiculatisporites largus Assemblage, and indicate a Visean age. The palynological data give the firmest age control available to date for the formation. A single sample suggests that deposition of the unit may have commenced in the Late Devonian - this material clearly represents the Famennian Retispora lepidophyta Assemblage.

2. Tertiary palynology. Early in 1977 a review paper was completed which integrates Tertiary palaeoclimatic data from Deep Sea Drilling Project drillsites in the Southern Ocean with palynological data relating to the vegetation history of Australia and Antarctica. This paper, the essence of which was presented at the International Geological Congress in Sydney in 1976, is now in press in Palaeogeography, Palaeoclimatology, Palaeoecology.

During 1977, an account of Australian climates from the beginning of the Miocene to the present day was compiled, in collaboration with R.W. Galloway, of the Division of Land Use Research, CSIRO. This account draws on data from a variety of sources in assessing climatic change; included are data from palynology, from weathering profiles, from vertebrate palaeontology, and from sea-level changes. The account forms part of a volume entitled Ecological Biogeography in Australia, which is edited by Allen Keast, and which is to be published by W. Junk, The Hague.

During 1977, a Cainozoic study group was formed within BMR, with B.R. Senior and M. Idnurm, with the aim of integrating research on Australian Continental Tertiary deposits.

D. Burger

1. Ronlow Beds Project. Palynological and lithostratigraphic work was completed on Jurassic and Neocomian sediments in the northeastern Eromanga Basin, Queensland. This study established the broad time relationship of the normal sediment sequence of the basin with the marginally developed sandy Ronlow Beds. These sands extend in outcrop from Hughenden south to Jericho

and so far have been dated "Jurassic to Lower Cretaceous", as firm palaeontological evidence for a more detailed assessment was lacking. The study also showed the influence of structural movements (Tara and Hulton-Rand Structures) on regional sedimentation. Several erosional phases were detected; the most important have been dated as Late Jurassic and (late) Neocomian from the absence of the upper Hooray Sandstone and the Cadna-Owie Formation. Shallow marine penetrations occurred in the Muttaburra and Longreach Sheet areas before the main Aptian transgression in Queensland.

2. Queensland Survey Drilling. Palynological work on three sections which were drilled by the Geological Survey of Queensland in the Tambo, Muttaburra, and Mitchell Sheet areas added considerable detail to the Upper Jurassic and Lower Cretaceous biostratigraphic and palaeoenvironmental picture at the eastern margin of the Eromanga Basin, which Burger described earlier. Several erosional phases identified further north could be continued as far south as the Mitchell Sheet area, and additional evidence was found of regional marine penetrations before the Aptian. These data will be presented together as a palynological and palaeoenvironmental account of the region.

3. Fourth International Palynological Congress. Text and projection slides were prepared for oral presentation of a paper entitled "Observations on the earliest angiosperm development, with special reference to Australia", and submitted to the Congress, which was held in Lucknow, India, December 1976. The paper was read by Mr B.S. Ingram, of Woodside Petroleum Pty Ltd.

4. RV Valdivia Expedition. Thirty samples from the Java Trench and Scott Plateau, off northwest Australia, were palynologically examined. The samples were collected during the Valdivia Expedition of 1976 and all except one were unsuitable for pollen analysis. They are probably of Recent to Subrecent age, and only one sample yielded a marine Late Jurassic palynoflora.

5. Carpentaria Basin Project. A study of spores, pollen, and marine phytoplankton from the Carpentaria Basin started in July. So far this work has covered Jurassic and Neocomian sediments (Helby Beds; Hampstead,

Loth, and Gilbert River Formations). It appears that the sequence was deposited in alternating marine and non-marine conditions, and that from mid-Neocomian times (the Foraminisporis wonthaggiensis spore interval) the entire basin was marginally marine. A detailed photographic and descriptive record is being made of the marine fossils, as they will greatly improve correlations with marine sequences in the Jurassic and Early Cretaceous of Europe and North America.

6. Curation. Curatorial work included the CPC collection and data storage processing (Computer Program); updating of existing edge-punch card collection of fossil dinoflagellate genera; re-arranging (in morphological order) of some 3500 cards of fossil spores and pollen genera (Spec. Publ. Dept. Geol. Univ. Calgary, Canada).

M.R. Walter

The study of the Adelaidean to Early Cambrian stratigraphy of central Australia continued with the preparation for drafting of 30 measured sections from around the southwestern margin of the Georgina Basin. Detailed mapping of parts of the Hay River, Tobermory and Mount Whelan 1:250 000 Sheet areas was undertaken in co-operation with C. Simpson, P.J. Kennewell, R.G. Warren and J.H. Shergold to allow a fuller interpretation of the structure and Adelaidean-Early Cambrian stratigraphy of that area. This was accompanied by a drilling program and is reported in more detail under the Georgina Basin Project.

Field work was undertaken with Dr W.V. Preiss and Mr R. Coats of the Geological Survey of SA in order to settle various controversies concerning the correlation of Adelaidean tillites within and between the Amadeus and Georgina Basins. Doubts about the correlation of the Areyonga Formation along the northern margin of the Amadeus Basin were settled by the discovery of an identical "cap dolomite" sequence in siltstones and shales overlying this formation in the Ellery Creek and Limbla areas. Subsequently the same cap sequence was found in the southern Georgina Basin, allowing the correlation of the Mount Cornish Formation and the newly defined Yardida Tillite with the Areyonga Formation, and the lower tillite of other Adelaidean basins. A different but equally distinctive "cap dolomite" was found above the Olympic Member of the Pertatataka Formation in the Amadeus Basin, confirming its correlation with the upper tillite of other Adelaidean basins.

Drs M. Idnurm and J.W. Giddings are presently attempting palaeomagnetic correlations of the tillites around the southwestern margin of the Georgina Basin and Dr P. Burek (Research Fellow, Australian National University) is attempting a palaeomagnetic correlation of the latest Adelaidean sediments in the Georgina and Amadeus Basins. This and the other work on Adelaidean stratigraphy reported above have been facilitated by the IGCP Working Group on Upper Precambrian Correlations, of which M.R. Walter is a member.

The study of microfossils and stromatolites from the Nabberu Basin was extended this year. A two-week trip to the basin was organised and run by Dr W.D.M. Hall of BHP primarily to allow the collection of cherts and stromatolites. Stratiform, nodular and bulbous stromatolites were collected in the iron-formation of the Frere Formation, in addition to previously reported oncolites. These, and the cherts from the Windidda Formation, are expected to yield microfossils. Silicified Conophyton stromatolites from the basal Bangemall Group were also collected because they appear potentially microfossiliferous. A comparative study of the microfossils and stromatolites of the Frere Formation and the Gunflint and Biwabik Iron Formations of North America is being undertaken in co-operation with Professor S.M. Awramik, University of California, under the auspices of the USA-Australia Science Exchange Agreement. A paper on the cyanophyte Frutexites from these two areas is being prepared.

Nine taxa of microfossils have been recognised in black cherts collected from the rim rocks of the Madley Diapir, Officer Basin, by A.T. Wells. These are presently being described and identified. Stromatolites from the Woolnough Hills diapir are also being studied.

A field and laboratory study of the Late Precambrian to Early Cambrian stratigraphy and palaeontology of the Sultanate of Oman was sponsored by Petroleum Development (Oman) Ltd (a subsidiary of Shell). During this work a tillite and associated "cap dolomite" were recognised. The sequence studied includes stromatolitic and evaporitic carbonates, and shallow-water siliciclastics. There are notable similarities with Adelaidean sequences in Australia.

The Third International Symposium on Environmental Biogeochemistry, in Wolfenbuttel, West Germany, was attended. Particularly useful aspects of this meeting included discussions on the roles of Mn and Fe depositing bacteria

in geological environments (e.g. the formation of deep-sea Mn nodules), and descriptions of modern evaporitic environments, some of which contain sulphur-cycling cyanophytes. It is apparent that it may not always be correct to interpret fossil cyanophytes as indicating oxygen release to the atmosphere. After the meeting Triassic stromatolites were examined in the field - it was for these that Kalkowsky coined the word "stromatolith" in 1908. Walter is on the Organising Committee for the fourth symposium, to be held in Canberra during August 1979. Planning for this meeting continued during the year.

Early in the year, five papers presented in the section "Life in the Precambrian" at the International Geological Congress in Sydney in 1976 were edited and have now been published as a special issue of Precambrian Research. Other activities associated with membership of the Editorial Board of Precambrian Research were continued.

Secretaryship of the Association of Australasian Palaeontologists continued during the year, involving assistance in organising palaeontological parts of the Second Australian Geological Convention in Melbourne, committee meetings in Melbourne and Canberra, and other duties.

In co-operation with P.A. Trudinger and D.M. McKirdy a project on "Early Organic Evolution and Mineral and Energy Resources" was formulated for and accepted by the International Geological Correlation Program. An initial task for this project will be to document Precambrian regoliths in Australia. Membership of the IUGS Working Group on the Precambrian/Cambrian Boundary involved providing data on central Australian stratigraphy and palaeontology, to facilitate international understanding of this transition and formal definition of the base of the Cambrian.

M.D. Muir

Dr M.D. Muir joined BMR from the Imperial College, London in July, and spent the remainder of the year with the McArthur Basin party. She is a specialist in Precambrian microfossils.

R.S. Nicoll

R.S. Nicoll completed a study of two conodont apparatuses which were found in the gut region of a palaeoniscoid fish from the Gogo Formation (Late

Devonian) of the Canning Basin, WA. One of the apparatuses, Oulodus angulatus has contributed significant information about the composition of elements in the Oulodus apparatus and about the nature of the basal attachment plate. The second apparatus, Icriodus brevis, is incomplete but gives information about the growth mode of some conodont organisms.

Work has also progressed on the study of Late Devonian conodont faunas from the Oscar and Napier Ranges, Canning Basin, WA. Identification of about half of the elements has been completed, but identification of multielement taxa of the fauna awaits computer analysis of the data.

A number of Silurian samples from the ACT and adjacent New South Wales have been examined and a few good conodont faunas have been recovered.

G.C. Chaproniere

G.C. Chaproniere is engaged in studies of Oligo-Miocene larger foraminiferids from Australia, and Oligocene to Recent planktic foraminiferids from the northwest of Western Australia.

A paper, coauthored with S. Shafik, dealing with the results of a combined study of nannofossils and planktic foraminiferal biostratigraphy from the 'Cartier Beds' of Ashmore Reef No. 1 Well has been completed, and a manuscript submitted to the editor of the BMR Journal. Zones N.3 and N.4 have been combined into Zone N.3/4, the base of which is characterised by the first appearance of Globigerinoides quadrilobatus primordius; this event occurs within the range of Neogloboquadrina siakensis opima, and typical late Oligocene nannofossils. A study of published literature indicates that this faunal relationship occurs in hemipelagic sediments elsewhere, although it was not recognised by the several authors concerned. In deep-water sediments Globigerinoides quadrilobatus primordius first appears above the extinction of Neogloboquadrina siakensis opima; Shafik & Chaproniere have explained this later appearance by suggested bathymetric shifts of the zone between the lysocline and calcium carbonate compensation level.

An additional paper, dealing with the biostratigraphy of the unnamed calcarenite, which conformably overlies the'Cartier Beds' in Ashmore Reef No. 1 Well, as well as the systematics of the planktic foraminiferids from both lithologic units, is nearing completion. Zone N.3/4 is overlain by Zone

N.5, which is characterised by the initial appearance of Globigerinoides quadrilobatus altiaperturus and by the extinction of Globorotalia (Fohsella) kugleri kugleri. Zones N.6 and N.7 have been combined into Zone N.6/7 because of the absence of the index species for these zones in the unnamed calcarenite. Because of the absence of the index for Zone N.6, Globigerinatella insueta, the first appearance of Globigerinoides quadrilobatus trilobus (sensu Blow) has been used to define this interval. The morphotypes nana, opima, acrostoma, siakensis and mayeri are seen to intergrade and form a distnct bioseries; for this reason they are recognised as subspecies of Neogloboquadrina siakensis. In addition a new species of Subbotina and a new subgenus of Globoquadrina are proposed.

Topotypes of Globigerina woodi woodi, from the Lakes Entrance oil shaft, have been examined. The range of variation strongly suggests a close relationship to G. praebulloides praebulloides, and that the wall ornamentations of the two forms intergrade. Both forms are known to give rise to Globigerinoides. The palaeogeographical distribution of the two forms suggests that G. woodi woodi is typical of temperate regions, and G. praebulloides praebulloides of subtropical and tropical regions. Research on the relationship of these taxa is continuing.

S. Shafik

S. Shafik has been engaged in systematic, biostratigraphic and palaeogeographic study of nannofossil assemblages from Upper Cretaceous to Holocene sediments of the Australian margin and offshore areas.

1. Nannofossil assessment of the top-metre sediments of Scott Plateau and Java Trench. Pronounced effects of bottom currents and a fluctuating Nanno Solution Depth are suggested to explain the distribution of nanno-fossils in the top-metre (average thickness) sediments of the Scott Plateau and Java Trench. Bottom currents are actively eroding parts of the central Scott Plateau and redistributing the fine fraction (nannofossils). Rocks of various ages are exposed on the sea floor of the central Scott Plateau, and wherever Pleistocene and younger nannofossil taxa are found on the Scott Plateau and Java Trench, they are mixed with (reworked) nannofossil elements which represent most of the stages of the Upper Cretaceous and Tertiary. Nearby areas with such admixing of nannofossils include the Deep Sea Drilling Sites 260 and 261.

Nannofossil evidence indicates that the Nanno Solution Depth is

between 3290 m and 4950 m at the present, but in earlier (Pleistocene) times it was at a deeper level, between 5251 m and 5290 m. This upward shift in the Nanno Solution Depth coincides with the increase in temperature which terminated the Pleistocene glaciations.

Comparison of the diversity of the genus Gephyrocapsa in the areas studied with that in areas surrounding Tasmania suggests that during the Quaternary-Holocene, temperatures of the surface-waters on the Scott Plateau and Java Trench were relatively high.

2. Nannofossil biostratigraphy of the Upper Cretaceous of the Perth and Carnarvon Basins. Systematic analysis of Upper Cretaceous sediments forming significant deposits along the Western Australia margin has resulted in a nannofossil biostratigraphic zonation with a resolution approaching 2 m.y. per zone; publication is awaiting its testing on sediments from the northern Australian margin.

On geological and geophysical grounds discrimination between the rock units in the subsurface of the Carnarvon Basin has been difficult. In this regard nannofossil results obtained appear highly significant. Identification of most of the rock units (from both outcrop and drill holes) seems possible by means of their nannofossil assemblages as each rock unit appears to contain a distinct nannofossil association. Routine nannofossil biostratigraphic work on prepared material can generally yield quick results as most of the important nannofossil species are distinct.

The study of the nannofossils of the Gearle Siltstone (from outcrop and drill holes) indicates that some subsurface occurrences of the formation include a younger unit not present in other subsurface occurrences or in outcrop. This unit is separated from the rest of the Gearle Siltstone by a biological break which coincides with a slight change in the lithology.

On nannofossil evidence the Gingin Chalk (Perth Basin) is correlated with the lower part of the Toolonga Calcilutite (Carnarvon Basin). Correlations of these two rock units and other units in the Carnarvon Basin have been extended to sediments in other areas (e.g. the Bonaparte Gulf Basin).

The nannofossil assemblages recovered include elements helpful in constructing palaeoenvironments. Collectively, shallow-water deposition in near-shore basin environments is suggested for the marine Upper Cretaceous sediments of the Perth and Carnarvon Basins.

PALAEONTOLOGY LABORATORIES

F. Hadzel continued general supervision of the palaeontological laboratories; in addition he prepared samples for micropalaeontological examination, and registered material added to the rock store, Fyshwick.

P.W. Davis prepared samples for micropalaeontological examination; he has also assisted with photography of microfossils, with curation of the foraminiferal collection, and with operation of the acid laboratory, Fyshwick.

A.T. Wilson has operated the acid laboratory, Fyshwick, in addition to assisting with illustration of ostracod faunas and with curation of the collections. He was in the field in the Mootwingee area, NSW, for four weeks.

Mrs L. Kraciuk was engaged in preparing samples for palynological examination and in registering and labelling slides and samples.

H.M. Doyle and R.W. Brown photographed macrofossils, prepared prints, assisted with preparation of macrofossil material, and prepared latex replicas of selected fossils. R.W. Brown was in the field in the Tirari Desert area for nine weeks.

A. Haupt prepared Precambrian samples and Devonian fish material for examination, and also continued with organising and registering the fossil and sample collections in the BMR Museum and at Fyshwick.

M. Ellis, A. Hughes, P. Brugman and S. Schmidt, trainee technical officers, were attached to the group during the year and gained experience in all aspects of laboratory work.

During the year 898 samples were washed for microfossil examination, and 1713 thin sections were prepared from a further 1159 samples; 158 samples were polished for preliminary examination. For nannofossil examination, 1112 slides were prepared from 562 samples.

In the acid laboratory, Fyshwick, 268 samples totalling 2050 kg were processed for extraction of conodonts.

The palynology laboratory prepared 758 slides from 213 samples for spore and pollen analysis.

BAAS BECKING GEOBIOLOGICAL RESEARCH LABORATORY

Convener, Operating Committee: A.R. Jensen

Executive Officer: P.A. Trudinger

STUDIES BASED ON SPENCER GULF

SEDIMENTOLOGICAL INVESTIGATIONS

by

R.V. Burne

STAFF: R.V. Burne, C.R. Madden

The study consists of a facies analysis of the recent sedimentary environments of parts of Spencer Gulf and aims at the production of a model to characterise the sequence of rocks that could be generated in this environmental complex. Such an understanding will assist the successful prosecution of geochemical and microbiological projects being undertaken in the area, and will enhance the interpretation of similar sequences preserved in the geological column.

The paralic environments of the Gulf include intertidal areas containing significant amounts of organic material, derived from seagrass beds offshore and, locally, algal mat colonisation, and supratidal areas in which gypsum is precipitated. Because of this they bear some resemblance to the sabkhas of the Trucial Coast, Arabian Gulf, and may, therefore, provide suitable sites for the experimental testing of various hypotheses which relate organic and inorganic chemical reactions within the sabkha environment variously to ore genesis and to the evolution of hydrocarbon source rocks.

The program, which commenced in February 1977, has concentrated initially on reviewing available data, maps, and aerial photographs, and on undertaking reconnaissance visits to this region to identify areas suitable for detailed study. The opportunity arose in May to implement an offshore sampling program by participating in a vibro-coring cruise mounted by Adelaide University. This resulted in the acquisition of a comprehensive suite of 38 cores from representative offshore environments. 18 cores (total length 34.6 m) were brought back to Canberra for sedimen-

tological analysis, 3 cores (total length 9 m) were destructively analysed in Port Pirie by Dr James Ferguson, and 17 cores (total length 40 m) were deep frozen soon after sampling, transported to Canberra and stored in a deep freeze to await biological analysis.

Although the project is still in its initial stages a reasonable conception of the depositional processes operating within the northern part of the Gulf has been evolved and the basis for an environmental model has been established. Winds and tidal current activity have constructed a number of prograding paralic sediment complexes (Fig. B1). The influence of fluviatile deposition is insignificant except perhaps for the poorly understood contribution of the Broughton River. The unusual tidal regime of the Gulf has fostered the development of an infrequently inundated supratidal environment in many of these complexes. The lower parts of these areas concentrate brines, and evaporite minerals may be precipitated. Figure B2 illustrates the nature of one of these prograding environmental associations by means of a facies map of the region north of Wood Point ($33^{o}23.5'S$ $137^{o}52.5'E$). Figure B3 shows an observed sequence in a core from a low sabkha location ($33^{o}23.6'S$ $137^{o}56.8'E$). The sequences examined to date have lacked two of the characteristic features of the Trucial Coast sabkha. Firstly, the evaporitic facies so far studied consist solely of gypsum (mainly discoidal) and halite. No anhydrite, celestite, or proto-dolomite has so far been observed (although proto-dolomite has been reported from the area by other workers). Secondly, regressive sequences containing buried algal mat material of intertidal origin in a reduced state have yet to be identified.

The program in the coming year will concentrate on the estimation of rates of sedimentation, description of sedimentary facies, and study of diagenetic and evaporitic processes.

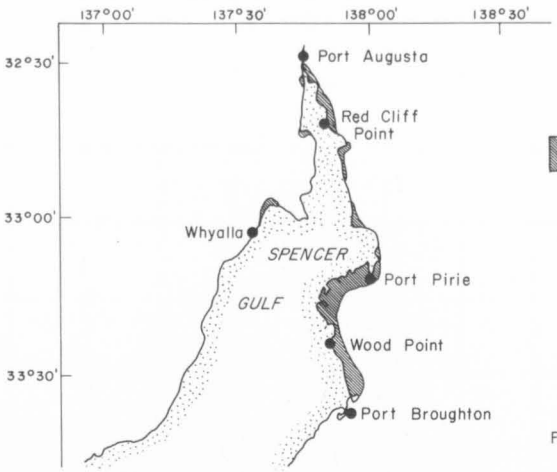


Fig.B1 Location of prograding paralic complexes, upper Spencer Gulf

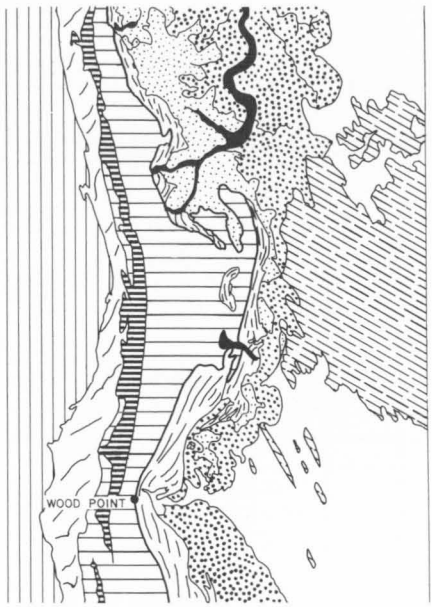


Fig.B2 Preliminary facies map of Wood Point area

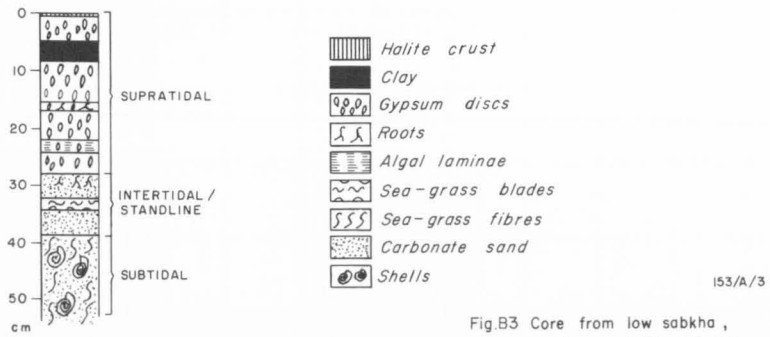


Fig.B3 Core from low sabkha, northeast of Wood Point

153/A/3

MICROBIAL ECOLOGY

by

J. Bauld (CSIRO)

The aim of this study is to determine the primary biological factors governing sulphur, metal and carbonate transformations in Spencer Gulf environments. Priority is being directed to a study of the factors controlling in situ rates of sulphide production in selected Spencer Gulf environments, with particular emphasis on the role of organic carbon.

A variety of sub-, inter-, and supratidal environments were inspected during field trips in May and August-September in order to assess their suitability for in situ studies of primary productivity and sulphide formation. Sediment cores were collected from a number of these areas. Vertical profiles of organic carbon and carbonate carbon have been determined for a supratidal core. Organic carbon constituted 0.3-2.5% of dry weight for both 63 m and 63-1000 m size fractions. Carbonate carbon values were somewhat higher, being in the range 0.7-5.0%.

An investigation into the feasibility of developing suitable extraction techniques for small molecular weight organic molecules in modern sediments has commenced (with L.A. Chambers). The planning stages have been completed for an investigation of algal mat primary productivity and carbon cycling in a laboratory-based simulated sedimentary environment (with G.W. Skyring and B. Bubela).

SULPHUR BIOGEOCHEMISTRY

by

P.A. Trudinger

STAFF: L.A. Chambers, M. Thomas, P.A. Trudinger (CSIRO)

Sulphate, sulphide and isotopic distributions in a core (19D) from an ephemeral lake south of Port Pirie have been determined. The pore waters from this core were highly saline and between about 4 and 34 cm depth the sulphate to salinity ratios were similar to those for sea water. In the top 4 cm the pore water sulphate concentration was anomalously high,

for reasons which are not clear at this time. Free sulphide (H_2S) concentrations in the pore waters were below the level of analysis. The acid volatile sulphide in the sediments of core 19D was low but shows a peak at a depth of about 11 cm. The ^{34}S values of this sulphide fell from -35°/oo at the base of the core (23-26 cm) to -18°/oo in the top 2 cm.

The data obtained so far are not sufficient to allow a detailed interpretation but do indicate that further studies are warranted.

Preliminary studies have also been made of an offshore core (Station 1) near the Port Pirie smelters. The pore waters from this core had salinities and sulphate concentrations close to those of sea water. The pore waters, except for the uppermost sediment layer, had, on average, about 35 mg L^{-1} of free hydrogen sulphide.

There was a major peak of acid volatile sulphide in the uppermost layer (0-15 cm) and lesser amounts in the subsurface layers. A large proportion of the latter sulphide was zinc-reducible (pyrite?). So far no isotopic data have been obtained.

STUDIES OF HEAVY METALS

by

James Ferguson

STAFF: B. Bubela, C. Robison (CSIRO); James Ferguson (BMR)

The purpose of this investigation is to establish the mechanisms by which heavy metal effluent from the BHAS smelters at Port Pirie is transported and fixed in sulphide-bearing sediments.

During the year, major effort was directed towards the identification of areas in Spencer Gulf suitable for the study of processes leading to the mobilisation and concentration of heavy metals in sediments. For this purpose a large number of water and sediment samples was collected in May 1977 for the determination of their heavy metal contents.

Results to date indicate that the BHAS effluent creek and adjacent offshore sediments are a suitable system to study the incorporation of metals from a metal-rich aqueous solution into a sulphide-containing sediment.

Features of this system include: (1) high dissolved Pb and Zn concentrations in the effluent waters; (2) a gradual decrease in these concentrations with distance from the mouth of the effluent creek; (3) probably, high metal concentrations in the upper (carbonate) sediments immediately offshore; (4) the presence of dissolved sulphide in the interstitial waters of the sediments and of a significant concentration of "fixed" sulphide in the uppermost layers. Areas where metal input from the smelters is in the form of a particulate aerosol would have limited use in the study of natural metal transport and concentration processes unless the metals deposited on the sediment surface were subsequently dissolved, thus losing the "memory" of their origin. Preliminary results from an ephemeral lake near Port Davis have shown that the uppermost sediments are slightly enriched in Pb and Zn but insufficient data are available yet to determine if significant mobilisation and redistribution of the aerosol particles has occurred. Selection of areas not influenced by metal emissions from BHAS will depend on their relevance to microbial and carbonate diagenetic processes.

USE OF RADIOACTIVE ISOTOPES IN THE STUDY OF THE RATES OF BIOLOGICAL PROCESSES IN NATURAL ENVIRONMENTS

by

G.W. Skyring

STAFF: M.H. Reed, G.W. Skyring (CSIRO)

A method similar to that used in the marshlands of Georgia (see below) was developed to measure rates of biological sulphate reduction in natural environments.

Using the labelled-rod technique, an attempt was made to assay rates of sulphate reduction in a column of sediment from an algal mat and from a salt pan in Spencer Gulf. Over the short period of incubation (24 hrs) sulphate reduction was not detected in either of these locations.

The labelled-rod technique is also being tested by a more rigorous series of experiments than those which were done in the United States.

STUDIES OF BIOLOGICAL SULPHATE REDUCTION IN COASTAL MARSHLANDS, GEORGIA, USA

by

G.W. Skyring (CSIRO)

From July 1976 to July 1977 Dr Skyring was employed as a visiting Professor in the Microbiology Department, University of Georgia, Athens, Georgia. As part of his teaching duties he wrote a laboratory manual on "Advanced Laboratory Techniques in Microbiology". This manual is now being used by senior students at that University.

Dr Skyring's research program was to develop and apply a method to assess the rates of sulphate reduction in various parts of the ecologically important marshlands which boarderthe coasts of the southeastern states of USA. Sampling of the muds from the marsh was sometimes complicated by the presence of a very thick mat of the roots of the marsh grass Spartina alterniflora. Homogeneous mixing of radioactive sulphate with such root filled samples was impossible. Some of the problems of assay were obviated by taking the sample in a sawn-off syringe and then inserting a small glass rod coated with radioactive, dried $Na_2{}^{35}SO_4$ through the centre of the sample. It was a novel idea in which physical alteration of the sample was kept to a minimum. The concept of the assay, which does not depend on the homogeneous distribution of radioactively labeled tracer, appeared to be validated by an experiment in which a positive linear correlation ($r = 0.92$) was found between the period of incubation (0 to 72 hours) and sulphide produced. These kinetics are applicable to a non-growing but physiologically active microbial population metabolising a substrate with a very large pool size.

The assay procedure was used to estimate the summer rates of sulphate reduction in the marshland for the tall Spartina and short Spartina zones. These zones represented the extremes of the Spartina-covered marshland. The rates were estimated to be 5.8 and 2.2 g S m^{-2} day^{-1} respectively for a column of soil 35 cm deep. When compared with the annual CO_2 primary fixation rates of 1697 and 601 g C m^{-2} yr^{-1} these rates of sulphate reduction are very high and they could not be sustained throughout

the year. Estimates of winter (December) rates of sulphate reduction for the tall and short Spartina zones were much lower at 1.1 and 0.06 g S m^{-2} day^{-1} respectively.

LABORATORY STUDIES

STUDIES IN FORMATION AND DIAGENESIS OF CARBONATES

by

B. Bubela

STAFF: B. Bubela (CSIRO); P.J. Davies, James Ferguson (BMR)

Previous work in the Baas Becking Laboratory indicated the importance of organic matter in the formation of carbonates. (See Geological Branch Annual Summary 1976). Further work has shown the molecular size of the organic matter is equally important to the chemical composition. This became evident from the work on carbonate ooids, where only fractions of humic acids having molecular weight greater than 20 000 were significantly active. It is believed that the molecular size plays an important role in the formation of organic membranes, a component in the mechanism of ooid formation.

Diagenesis of certain carbonates is affected by organic material as well. Amino acids are capable of inhibiting or enhancing the conversion of aragonite to calcite. This activity seems to be correlated with the isoelectric point of the acids. Isoelectric point is a pH value at which a molecule has no net electric charge. Acids with high isoelectric point (asparagine, pH 10.76) enhance the conversion, while acids with low isoelectric point (aspartic acid, pH 2.98) inhibit the process. Acids with an intermediate value (glycine, pH 6.064) are inactive. The effect of the amino acids is affected by the ionic strength of the experimental solution. Other compounds, besides amino acids, having an isoelectric point are being investigated.

SULPHUR ISOTOPE FRACTIONATION DURING SULPHITE REDUCTION

by

P.A. Trudinger

STAFF: L.A. Chambers, M. Thomas, P.A. Trudinger (CSIRO)

In the last Geological Branch Summary of Activities it was reported that, in addition to sulphide, thiosulphate is a major product of the biological reduction of sulphite. Since thiosulphate is now known to be a significant component of the sulphur pool in sediments, the isotopic effects during its formation in the biological system were examined.

During sulphite reduction by the anaerobic bacterium Clostridium pasteurianum, there was an enrichment of ^{32}S in thiosulphate, mainly in the outer, reduced sulphur atom. This pattern of enrichment was also found during the chemical formation of thiosulphate from sulphite and hydrogen sulphide. In the biological system an inverse isotope effect, namely enrichment of ^{34}S in H_2S during the later stages of the reaction, was noted. Such an effect had been reported earlier by other workers.

Thiosulphate was also formed in large amounts during sulphite reduction by the sulphate-reducer Desulfovibrio desulfuricans. In contrast with Cl. pasteurianum, however, virtually no fractionation in H_2S was found.

SIMULATED SEDIMENTARY SYSTEMS

by

B. Bubela

STAFF: B. Bubela, I. Johns, C.R. Robison (CSIRO); James Ferguson (BMR)

Development of simulating systems. A system capable of simulating a variety of parameters present in evaporative sedimentary environments has been developed. Its hydraulic components are capable of providing horizontal and vertical movement of waters through the sediments and establishing and holding a water table at required levels. The thermal component provides heat and illumination of required

intensity and duration. Coring, sampling and monitoring facilities are provided so as to minimise the disturbance to the system.

At the present time the system is programmed to simulate a number of parameters present in "sabkha" environments.

To achieve the cycling periodicity of some of the parameters required in the simulating systems, an electronic component was developed capable of controlling a number of systems simultaneously, representing a variety of environments. The main electronic control consists of two sections, one initiating and terminating events at preselected times, the other providing long-duration facilities with adjustable recycle period. Time intervals of 1 second to 3.5×10^5 seconds can be programmed. All channels contained in the control unit are mutually independent, allowing time overlap and non-sequential operation.

One control program currently operating involves simulation of normal tides, on which spring tides are superimposed, drought seasons, and the temperature and light cycles involved in the sabkha environment.

Studies of heavy metals. To study the fate of airborne particles consisting of a variety of chemical compounds of heavy metals as encountered in certain parts of Spencer Gulf, a simulating system was developed. Particles are introduced in dry form to the surface of a water column and their behaviour on the surface, during their transit through the water column up to 3 m deep, and after their burial in sediments, and their physico-chemical and mineralogical composition are observed.

The system designed to study the solid particles as described above is also controlled by the master unit. Regulated quantities of the particles are added to the system at preselected times and wave motion is introduced to the water surface as required.

ORE GENESIS INVESTIGATIONS

INVESTIGATIONS OF COUNTRY ROCK ALTERATION AROUND MASSIVE Cu-Pb-Zn DEPOSITS IN FELSIC VOLCANIC SEQUENCES, SOUTHEASTERN NEW SOUTH WALES

by

I.B. Lambert (CSIRO)

The main aim of these studies has been to elucidate details of the nature and distribution of alteration aureoles around massive sulphide mineralisation, thereby obtaining information which is essential for establishing metallogenetic models and exploration guides.

Captains Flat and Orange areas

Data previously obtained from the Captains Flat and Orange areas have now been assessed and it is apparent that the geochemical and mineralogical trends around the massive deposits in these areas are basically similar to those at Woodlawn (last year's report). In each case, the country rocks consist of coarse lithic tuffs, quartz porphyroids and tuffaceous shales which have been silicified, sericitised and chloritised at the expense of primary feldspars and ferromagnesian minerals. The altered rocks are characteristically enriched to varying degrees in Mg, Fe, Si, S, Mn, Ba, Cu, Pb, and Zn, and depleted in Na and Ca (except sedimentary carbonates).

The distributions of the altered rocks have not been defined with any precision at Captains Flat and Orange. At Captains Flat, there is sporadic alteration along the probable ore horizon for at least 5 km from the old mine and the alteration becomes more marked within about 500 m of the massive mineralisation; in the footwall, it extends for at least 100 m beneath the mineralisation, the deepest level sampled, but alteration in the hangingwall appears to be relatively limited. At Orange, alteration around both the Lewis Ponds and Mount Lindsay prospects has been shown to persist for at least about 60 m into the footwall and 20 m into the hangingwall, but its extent along strike has not been tested.

REDBANK COPPER PROSPECT

by

J. Knutson

STAFF: T.H. Donnelly, I.B. Lambert, (CSIRO); John Ferguson, J. Knutson, W.M.B. Roberts (BMR)

The investigation of the Redbank copper prospect was initiated in order to determine the source of copper mineralisation in the area and to suggest guidelines for further prospecting efforts.

The Redbank area is characterised by the occurrence of copper-bearing breccia pipes in a stratigraphic succession which includes the Settlement Creek Volcanics consisting of basic and intermediate igneous rocks; the Wollogorang Formation, essentially dolomite with some sandstone and siltstone; the Masterton Formation, comprising the intermediate and basic Gold Creek Volcanics; the Packsaddle Granite and its extrusive equivalent; the Hobblechain Rhyolite and undifferentiated sediments including quartz sandstone, conglomerate and feldspathic sandstone. The igneous rocks, and to a lesser extent the sedimentary rocks, in the area have undergone widespread K-metasomatism.

The steeply inclined breccia pipes are of limited size and cylindrical form and typically show in situ brecciation. Cementing material in these pipes and associated veining includes microbreccia, dolomite, quartz, chlorite, hematite, K-feldspar, apatite, chalcopyrite, barite, pyrobitumen, rutile, and galena. K-metasomatism is more intense in the vicinity of the breccia pipes and carbonate veining and there is textural evidence indicating that fluids rich in K, Cl, Fe, P, Mg, CO_2, and H_2O were introduced into these rocks.

Carbon and oxygen isotope data and Ce and La values for some of the carbonate vein and breccia pipe infillings indicate that this carbonate has a magmatic origin. Data for other samples suggest there has been mixing of carbonate from magmatic and sedimentary sources.

It is concluded from the general association of magmatic carbonate and K-metasomatism that the fluids responsible for the K-metasomatism were in equilibrium with a carbonatitic K-rich silicate melt. The breccia

pipes formed by explosive pressure release following the build-up of significant over-pressure in the magma chamber as the result of gas expansion at 2-3 km depth.

Sulphur isotope values indicate that copper and leach mineralisation in the lower levels of the breccia pipes also has a magmatic origin, although there is evidence that much of the stratigraphically higher mineralisation has been remobilised and redeposited.

INVESTIGATION OF COPPER MINERALISATION, ADELAIDE GEOSYNCLINE AND STUART SHELF, SOUTH AUSTRALIA

by

I.B. Lambert

STAFF: T.H. Donnelly, I.B. Lambert (CSIRO); J. Knutson, W.M.B. Roberts (BMR)

At the present time, there is a considerable amount of exploration for stratabound copper deposits in the Upper Proterozoic sedimentary strata of the Adelaide Geosyncline/Stuart Shelf region. This has been spurred on by recent discoveries of mineralisation of this type at several localities in this province.

The main objective of our studies is to compare and contrast the isotopic, geochemical, mineralogical, and petrographic features of mineralised and unmineralised strata from several areas through the region, in an attempt to define metallogenetic processes and exploration guides. Initially, we are concentrating on the Kapunda, Mount Gunson-Lake Dutton, and Myall Creek areas.

Kapunda area (Utah Joint Venture). A preliminary suite of approximately 30 drill-core samples has been collected and isotopic compositions of their sulphide and carbonate minerals have been determined. The ^{34}S, ^{13}C and ^{18}O values all show wide spreads, and meaningful interpretation of the data will only be possible when additional samples have been analysed. Selected carbonates have been submitted for partial chemical analyses.

Mount Gunson-Lake Dutton area (Pacminex). Stable isotope and petrographic investigations are under way on approximately one hundred samples from drill cores through the area and hand specimens from the Cattle Grid open cut. Approximately 90 drill-core samples have been submitted for whole-rock analyses. The isotopic measurements have defined a wide range of ^{34}S values.

Myall Creek area (Australian Selection). About 65 samples have been collected from drill cores and are currently being prepared for isotopic, geochemical and petrographic studies.

STABLE ISOTOPE STUDY OF THE NORTH POLE BARITE DEPOSITS, PILBARA, WESTERN AUSTRALIA

by

T.H. Donnelly

STAFF: T.H. Donnelly (CSIRO); I.B. Lambert (CSIRO) in collaboration with J.S.R. Dunlop and D.I. Groves (University of Western Australia).

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). The North Pole barite deposits are important because of the rarity of Archaean sulphate deposits. Specifically, this study is designed to assess the source of the sulphate, and it is hoped that the data will place constraints on the geobiochemical evolution of the Earth.

The isotope data obtained in a preliminary study of this deposit are at present being interpreted. As well, Dunlop (University of Western Australia) worked for a month in the Baas Becking laboratory learning techniques and completing further samples. To date, the data obtained indicate a lack of isotopic equilibration between coexisting sulphate/sulphide and no isotope differences between bedded and vein barite. Oxygen isotope ratios of the barites fall within a narrow range and are more ^{16}O-

enriched than gypsum, anhydrite, and barite from Upper Proterozoic and younger evaporites. The results obtained in the North Pole area will also be compared with those obtained on samples from Archaean bedded barite from South Africa (Swaziland System).

OVERSEAS VISITS

G.W. Skyring:

Dr G.W. Skyring was on leave of absence from July 1976 to July 1977, during which time he was a visiting Professor in Microbiology at the University of Georgia, Georgia, USA. While there, he was engaged in research on sulphur transformations in coastal marshlands and in teaching an advanced microbiology course. He presented seminars at the schools of Microbiology, Biochemistry, Geology and Marine Science at the University of Georgia and also at the Clemson University in South Carolina. He attended the American Society for Microbiology Conference on Nitrification and Reduction of Nitrogen Oxides in September 1976 and the Annual General Meeting of that Society in New Orleans in May 1977. In collaboration with colleagues two papers were presented at the latter meeting.

During his return trip he visited the Department of Geology at the University of Stockholm. There has been a close liaison between this institution and the Baas Becking Laboratory over the past few years. Much of the experience gained by Dr Skyring will be useful in research recently commenced in Spencer Gulf.

P.A. Trudinger:

Dr. P.A. Trudinger visited Europe in March where he attended and presented a paper at the 3rd International Symposium on Environmental Biogeochemistry. Some laboratories in Germany and The Netherlands were also visited.

GEOLOGICAL SERVICES SECTION

Head of Section: E.K. Carter

GENERAL

At the end of February the three Drawing Offices of the Bureau were amalgamated and were transferred to the Operations Branch. The activities of the Geological Drawing Office for the whole year are reported in the Operations Branch Annual Summary of Activities.

The activities of the Engineering Geology Subsection reflected the trend of the previous year towards a greater geographical spread of work, with contributions to Australian aid projects in Indonesia and to a tunnel project in Melbourne. The greatest activity, however, remained in the ACT and environs, where geological services continued to be provided for two major engineering projects under construction. An important contribution was also made to the study of a serious problem of groundwater pollution by hydrocarbons in Civic. A wide variety of problem-solving activities, engineering project investigations, soil stratigraphic studies, and geological and geotechnical mapping was maintained through the year.

Museum facilities were in even greater demand than before, with increased visitor numbers, several exhibitions, and additions to the collections. A highly successful collecting operation from Browns Deposit, Rum Jungle, NT was mounted.

Map editing services adequate for demand were provided.

Steady progress was made with a heavy program of map compilation, but no new maps produced in the group reached the printing stage during the year.

Surveillance of the current literature and indexing of stratigraphic names noted were maintained satisfactorily and other services provided despite staff shortages. In the latter part of the year work on technical files and the mineral index ceased owing to diversion of staff to higher-priority work.

The Section Head attended a UNESCO Seminar on Science and Technology Museums and visited Rum Jungle and the Mount Isa-Mary Kathleen area during the year. He contributed to the session "What maps are needed now?" at the 6th BMR Symposium. With Mr E.G. Wilson he also took part in literature studies of nuclear waste disposal.

ENGINEERING GEOLOGY

Staff: E.G. Wilson, G. Jacobson, D.C. Purcell, G.A.M. Henderson, P.D. Hohnen (part-time), P.H. Vanden Broek, L.F. Macias (from September), R.C.M. Goldsmith
Technical Officer: J.R. Kellett; Technical Assistant: A.W. Schuett; Field Assistants: R. Evans, D. Guy, R. McPake, R. Starke

GENERAL

Many investigations reported below were carried out jointly with the Engineering Geophysics Group with which 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. GS1.

ENGINEERING GEOLOGY FOR CANBERRA'S WATER SUPPLY AND SEWERAGE SYSTEMS

by

D.C. Purcell, P.H. Vanden Broek and R.C.M. Goldsmith

Engineering geology services for the investigation, design and construction of Canberra's water supply and sewerage works were provided for the Department of Construction (D of C).

Googong Dam and appurtenant works

Construction of the Googong Dam and spillway was nearly complete by 1 October 1977. One month before the 60.5 m embankment was completed the diversion tunnel was plugged and the reservoir began to fill (March 1977). The reservoir reached a level of 645 m R.L., 25.5 m below top water level, by 1 October 1977. Prior to commencement of filling, the geology of the reservoir area was mapped at a scale of 1:10 000.

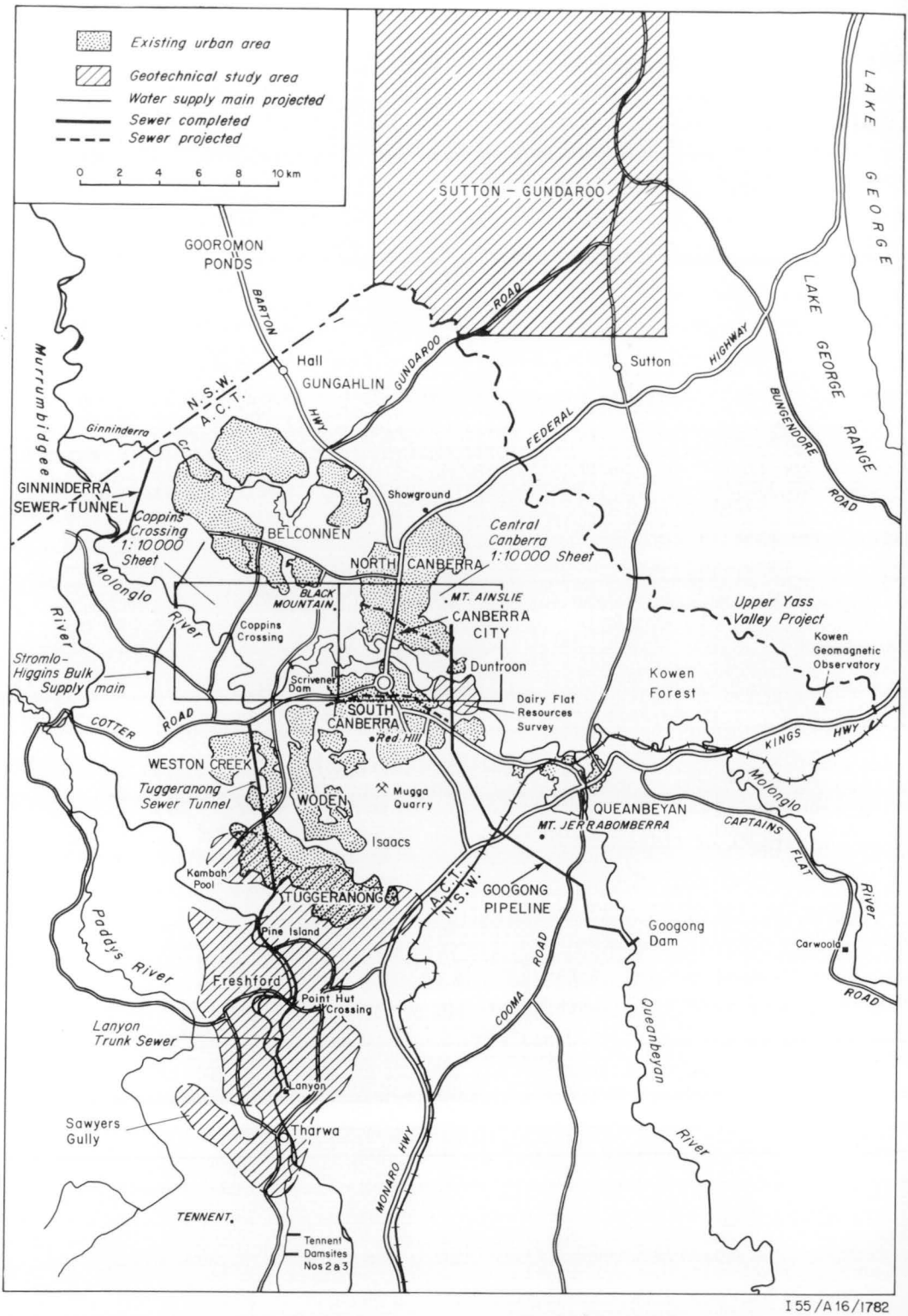


FIG.GS1 Urban Geology; Locations of projects, Canberra and adjacent areas, 1977

Geological features of the embankment core zone foundations were mapped at 1:200 scale and advice was given on foundation treatment and stability of the abutments. A major clay seam on the right abutment required special grouting and clean-up to ensure its stability.

Excavation for the spillway approach channel, chute and energy dissipation pool is complete. The excavated material - dacite and granite - where suitable was used as rockfill in the dam embankment. Shale and sandstone lenses and sheared zones in the dacite were unsuitable for rockfill, as was granite from a fault zone in the energy dissipation pool. As a significant proportion of material was rejected, additional rockfill material was excavated from an area located 30 m upstream from the spillway crest. By avoiding sedimentary lenses this material proved satisfactory.

The foundations of the spillway crest and chute were mapped in detail to determine leakage paths and areas of unsuitable foundation rock, before concrete lining began. The dacite is fractured, with closely spaced joints and clay seams, but is generally impermeable.

Grouting of the dam foundations, spillway crest and cut-off trenches was completed during the year. Grout consumption in the curtain line of the dam was generally low (average less than 0.4 bag/metre). Some inclined holes were grouted in pervious granite in the left abutment. Nearly 800 blanket holes were grouted, and takes were high (up to 17 bags/metre) where holes intersected geological defects. Grouting in the spillway was successful with low takes in both the grout trenches upstream and downstream of the spillway chute.

A 10 m high earth embankment in the saddle to the east of the main embankment was completed.

Construction of the pumping station and water treatment plant continued during the year. All excavations were completed and conditions were generally as predicted. Foundations for the filter had some overbreak.

The 22 km pipeline from the dam to Campbell Reservoir was begun in February 1977 and the section in the ACT has been completed. Work is currently under way on the NSW section. Exposures in the trenches have provided valuable information on the geology along the route.

Stromlo-Higgins water supply main - Stromlo Tunnel

A tunnel under part of Mount Stromlo was constructed between 17/10/76 and 22/6/77 as part of a route from Stromlo Water Treatment Plant to Higgins Reservoir. The 273 m long tunnel section was necessary in order to maintain a 1:200 grade for the route.

Advice was given to the Department of Construction during excavation of the portals and tunnel, particularly with regard to stability and support. The tunnel was shallow and was excavated mainly in moderately weathered dacite. Tunnelling conditions were generally fair to poor. A report on construction conditions was prepared after tunnel completion. Back calculations were also carried out to test the accuracy of predictions (seismic and geological) made in the pre-construction report. Rock conditions were generally slightly better than predicted.

Tuggeranong Tunnel inlet structures

Excavations up to 15 m deep for sewer pipes connecting to Tuggeranong Tunnel from various suburbs of Tuggeranong required stability analysis studies during construction. Advice was given to the Department of Construction. Several sets of unfavourably oriented joint planes caused major collapses in sections of the excavations. The main concern was for the safety of personnel during excavation and pipe-laying, and through co-operation between BMR, D of C, and the contractor, the safety of personnel was assured.

Ginninderra Sewer Tunnel

The purpose of the Ginninderra Sewer Tunnel is to convey sewage from the existing Belconnen Water Pollution Control Centre to the new Lower Molonglo Water Quality Control Centre, thereby ensuring that future waste water from the Belconnen and Gungahlin urban development areas is properly treated before discharge into the Murrumbidgee River.

The scheme consists of two 2130 mm diameter concrete-lined tunnels, 4240 m and 890 m long, connected by 120 m of pipeline buried in an embankment of excavated rock. Excavation of the shorter tunnel started on

the downstream heading on 21 October 1976 and was completed on 26 April 1977. Excavation of the upstream heading of the longer tunnel commenced on 13 November 1976 and is at present (October 1977) 1400 m in from the start point. One of the three shafts (Shaft 3) to the tunnel has been excavated. An additional 3350 m of tunnel remains to be excavated.

Mapping of the tunnel is carried out as excavation progresses, taking particular note of rock conditions, support used, and groundwater inflows. Department of Construction engineers are advised on expected conditions ahead of the face and on problems of a geological nature as they occur.

The downstream tunnel, 890 m long, was excavated in blue dacite with an overall shallow southwesterly dip. Rock condition was generally good with only 12 percent support being required along the section; most of the section was in blocky and closely jointed rock with about 250 m of fresh, moderately jointed rock and 220 m of fresh widely jointed rock.

The upstream heading has so far been excavated through rhyolite, dacite, siltstone, granite porphyry, granite, and adamellite. Excavation conditions have generally been a little worse than expected with 95 percent of the rhyolite, 34 percent of the dacite, and 25 percent of the granite requiring support. Overall, 44 percent of the upstream heading has been supported by steel sets; however, tunnelling conditions will be much improved in the remaining section.

Groundwater inflows, though initially high in a few places (up to 7000 litres per hour) have generally subsided after a few weeks and are only a nuisance to the contractor. Significant groundwater inflows, adjacent to faults and seams, will become pressure grout targets once the tunnel has been lined with concrete.

ENGINEERING PROJECTS ELSEWHERE IN AUSTRALIA

by

D.C. Purcell

Telecom Cable Tunnel, Melbourne

A study has been undertaken for the Department of Construction, Melbourne, to determine the feasibility of a tunnel under Queen and Lonsdale Streets in the City of Melbourne. The tunnel is to house Telecom cables and will be about 2100 m long at an average depth of 12-15 m below the

road surface. BMR's role is to supervise the geological investigation and to assist in the preparation of a design report suitable for inclusion in an information-for-tenderers document.

Diamond drilling of the route was completed late in September and comprehensive testing of rock and soil samples commenced in October. Drilling has revealed that about 50 percent of the tunnel is expected to be in poor rock which includes alluvium, weathered basic dykes, fault zones, and extremely to highly weathered mudstone.

Hugh and Finke River railway bridges, Central Australian Railway, NT

A review of a geological report on the Hugh and Finke River railway bridge sites was made for the Mines Branch, Department of the Northern Territory.

WATER SUPPLY PROJECTS IN INDONESIA

by

G. Jacobson

Urban water supply developments in three Indonesian cities are being considered as part of an Australian aid program being administered by the Australian Development Assistance Bureau. The potential for development of groundwater as well as surface water was studied on an appraisal mission to the three cities - Tanjung Karang and Kota Bumi in southern Sumatra, and Cilacap in central Java. The mission included engineers from the Department of Construction and a sociologist in addition to a BMR geologist. Groundwater supplies are preferred wherever possible, as they do not require extensive treatment before use.

Tanjung Karang

Tanjung Karang is a rapidly developing urban centre, being the capital and port for Lampung Province in southern Sumatra. The population is expected to reach 500 000 in a few years' time, and only a small proportion can be supplied with water from the present reticulation system. The area

is one of volcanic rocks that in places yield groundwater to bores and springs. Some underground water sources can possibly be developed in the near future to meet some of the city's needs, and this would delay by several years the need to construct expensive headworks for impounding surface water that will eventually be required for this rapidly growing centre.

Kota Bumi

At Kota Bumi, an inland town of 100 000 people and centre of an important agricultural district, geological evaluation has indicated the existence of underground water. It is expected that the entire town supply can be derived from deep bores to a sandstone aquifer, thus avoiding the cost of surface water storage and a treatment plant.

Cilacap

Cilacap is a developing port and industrial centre on the south coast of central Java. Geological evaluation has indicated that there is insufficient groundwater available in the vicinity of the city; however, other groundwater sources at some distance from the city are being evaluated and the cost of their development is being compared with that of possible sources of surface water.

HYDROGEOLOGY

by

P.D. Hohnen, G. Jacobson, and J.R. Kellett

Canberra City groundwater pollution study

A fatal accident occurred in the Center Cinema in Canberra City in February when hydrocarbons and explosive vapours in the cinema basement were ignited whilst pipes were being welded. A detailed investigation of the hydrogeology of the city was commenced, and an area in which groundwater was polluted by hydrocarbons was delineated adjacent to the cinema.

Thirty drill holes were constructed to define the extent and thickness of the pollution plume, and to monitor its movement. Permeability

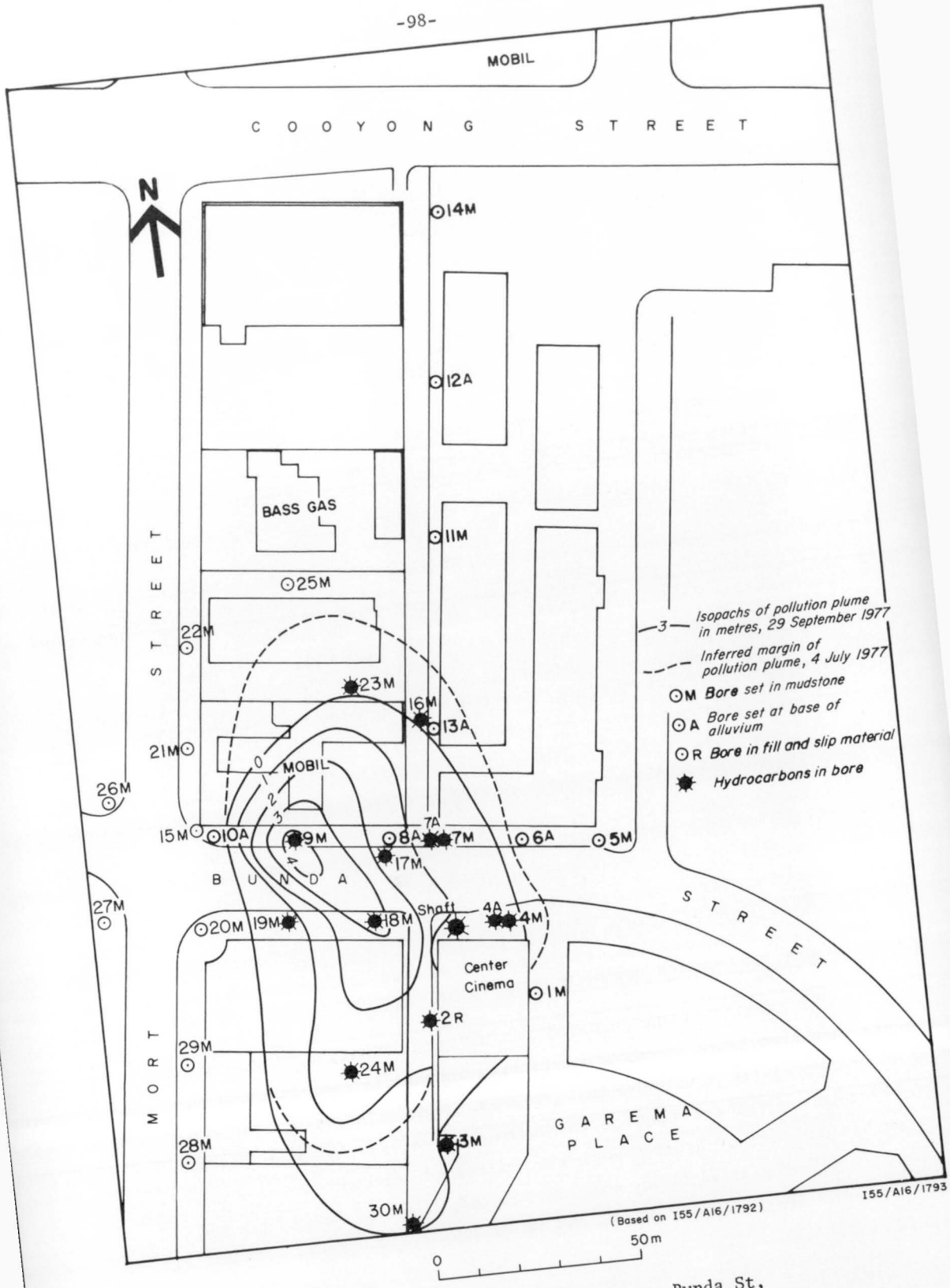


FIG.GS2 Hydrocarbon pollution of groundwater, Bunda St, Canberra City

tests were carried out in the drill holes, and a dye tracing experiment was conducted by others to investigate groundwater flow direction and velocity. Groundwater is present in the base of the alluvium and in the fractured Silurian mudstone below. A lenticular hydrocarbon pollution plume in the groundwater (see Fig. GS2) which has been estimated to contain about 32 000 litres of supergrade petrol, may have originated from a service station upstream of the cinema.

Recovery operations were initiated by construction of a shaft to remove some of the pollutant. A more effective recovery system involving pumping from a deep bore has been proposed. Geological advice on this matter was given to the Department of the Capital Territory, the National Capital Development Commission (NCDC), and the Department of Construction. Evidence was given at the Coroner's Court enquiry into the cause of the explosion and fire.

Groundwater seepages at "Freshford", West Murrumbidgee development area

Investigation of groundwater seepages at "Freshford" was carried out at the request of NCDC. The nature of the soils, the geology, and groundwater levels were determined, and the location of the Murrumbidgee Fault was accurately determined. Recommendations were made to the planners and engineers concerned with design studies for urban development.

Groundwater in shallow aquifers in the soils is derived from fractured-rock aquifers below. The surficial soils above the shallow aquifers become saturated and in many places maintain that condition throughout the year. Appropriate drainage measures have been recommended, and the suitability of foundation materials for urban development has been assessed.

Duntroon waste-water re-use project

NCDC is testing public acceptance of the use of partly treated effluent for spray irrigation of playing fields at the Royal Military College, Duntroon. Soil cores were taken at seven locations to estimate permeabilities and the travel times for the underground movement of effluent from its point of infiltration to arrival at Lake Burley

Griffin. Soil depths were generally greater than four metres, and groundwater was intersected in each hole. Samples were taken from the holes for biological analysis by others. The project has not yet been implemented.

Lanyon drainage investigation

Investigation continued of two areas subject to waterlogging, which are unsuitable for urban development without improved drainage. The frequency of recording of groundwater levels in the two basins was reduced to about 6-weekly intervals during the year. The purpose of the study is to develop the most efficient method of treatment, and for this purpose a computer-based model of the groundwater system was developed last year.

Testing of the groundwater model by comparison with observed values of the hydraulic head near the basins' boundaries was completed. The calibration was based on readings taken during September-November 1976. Groundwater recharge from rainfall was estimated from infiltration rates at field capacity, determined earlier in the investigation.

The diamond-drill holes were fracture-logged and correlation coefficients between readings in the alluvium and those of the fractured rock were brought up to date; in most bores it was possible to derive a linear equation relating the hydraulic head in the alluvium to that of the fractured rock.

Several visitors from interstate and overseas were shown over the basins during the year.

Upper Yass River valley joint hydrological study

A joint study with CSIRO is being undertaken of the hydrology of a basin of about 300 hectares in the upper Yass River valley, with BMR contributing the groundwater hydrology. The basin is one of the Representative Basins selected by the Australian Water Resources Council to categorise Australian hydrological basins.

Following preliminary geological and soils mapping, a bore was drilled to 30 m in the fractured rock on the watershed to define the boundary conditions there. Nineteen holes have been drilled by others in the alluvium in the lower part of the basin, and fourteen of these have been equipped by BMR as piezometers.

There are at least two non-leaky aquifers in the alluvium through which lateral outflow from the basin occurs, and it appears that these are not in hydraulic continuity with the fractured rock aquifer. It is intended to place emphasis on the investigation of the hydraulic properties of the fractured rock and infiltration from rainfall through the clays to the alluvium as a function of the antecedent precipitation.

Surface hydrological data are being gathered by CSIRO from the instrumentation that has been installed by them in the basin.

URBAN GEOLOGY, A.C.T. AND ENVIRONS

by

G.A.M. Henderson, G. Jacobson, P.D. Hohnen, J.R. Kellett, P.H. Vanden Broek and R.C.M. Goldsmith

ACT landfill sites

Investigations were carried out for the National Capital Development Commission (NCDC) of several sanitary landfill sites in the ACT.

At the two main operating sites - Pialligo and West Belconnen - groundwater conditions were investigated by drilling, and leachate monitoring bores were established. At Pialligo a groundwater pollution plume was identified that extends several hundred metres from the site.

Five alternative prospective sites to serve South Canberra and Tuggeranong were investigated by seismic surveys and drilling to ascertain excavation conditions and groundwater pollution potential. Two of the sites were eliminated on geological grounds. The selected site in Mugga Lane was further investigated to aid design of the trenches and leachate control system.

Dairy Flat sand and gravel resources, ACT

A report was prepared on sand and gravel investigations carried out at Dairy Flat in 1975 and 1976. Seismic refraction traverses, resistivity surveys and augering delineated sand and gravel reserves of about 5 million cubic metres. Auger testing extended to a maximum of 10 metres depth.

Regional survey for airport sites

A survey of airport sites was requested by NCDC to enable planners to set aside an area for a long-term alternative or additional airport site for Canberra.

Ten sites were investigated from engineering geology and environmental geology viewpoints, taking into account such factors as foundation conditions, excavation characteristics, topography, groundwater conditions beneath the site, and local drainage. A report was prepared and a preliminary copy was forwarded to NCDC.

Regional sand and gravel survey, Canberra and environs

Doubt has been expressed as to the availability of sufficient quantities of coarse river sand within economic transport distances to meet the demands of the building industry to the year 2000, and a survey of sand and gravel deposits in the Canberra region was requested by NCDC. The major part of the study was carried out in 1976. Additional information on deposits and their development has become available recently and has been included in the report on the survey.

The study has revealed that sand deposits in the Murrumbidgee River are larger than had been previously thought; there is a possibility of larger deposits being worked to the south of Lake George, and there are very large deposits in the Burrinjuck Dam, at Bredbo, and in the upper Shoalhaven River valley.

Present use of coarse river sand in Canberra is about 600 000 cubic metres per annum, and it could be expected to rise to 1-2 million cubic metres in the 1980s and to 2-4 million cubic metres in the 1990s. Reserves of 50 million cubic metres will be required for extraction before the year 2000. The study concludes that known reserves and current replenishment rates indicate that transport distances of 80 km are unlikely to be exceeded during this period, and that the transport component of sand costs is expected to stabilise.

Minor projects

Brief reports were prepared or advice tendered on many minor projects in the ACT for our various clients; the projects are briefly listed below.

Googong-Red Hill water main: Excavation conditions en route such as hard rock, groundwater, and route alternatives assessed.

Canberra Showground: Poorly drained soils examined.

Paddy's River 'gravel' deposit: Reserves remaining in present pit estimated.

Isaacs Hill and Wanniassa 2 reservoir sites: Foundations investigated for Department of Construction.

Gungahlin brick pit: Source of lime in brick shale determined.

Tuggeranong Creek weir sites: Geological and geophysical surveys of alternative sites undertaken.

Eastern Parkway corridor: Foundation conditions assessed for a 3-6 m high embankment across Dairy Flat.

Molonglo Parkway quarry: Rock quality and quarrying techniques investigated.

Coranderrk drainage problem: Instability in trenches and remedial works for drainage problem investigated.

Reid foundation investigation: Geological and geophysical investigations for 2 and 4-storied flats at rear of Bega Flats undertaken.

Tuggeranong Freeway, Cotter Road and Hindmarsh Drive overpasses: Foundation conditions for bridges assessed for Department of Construction.

MAPPING PROJECTS

by

G.A.M. Henderson and J.R. Kellett

Canberra 1:50 000 geological map

Compilation of a revised 1:50 000 scale map was completed during the year. The map has been extended south to include Tuggeranong, and now covers all of the present and foreseeable urban area of Canberra. Additional detailed mapping at 1:10 000 scale for construction of sewer tunnels has clarified the distribution of the various volcanic rocks to the west of Canberra. Their stratigraphic succession has also been resolved to a considerable extent by chemical analyses done in 1974 and 1975, which have established systematic chemical differences between Silurian and Devonian volcanics.

Revised explanatory notes are being prepared.

Canberra 1:10 000 engineering geology maps

Compilation of several maps in the engineering geology series of standard 1:10 000 maps is in progress. The first map in the series, the Coppins Crossing sheet, was compiled and its accompanying explanatory notes were written. Those being compiled are: Central Canberra and Woden-Weston Creek (well advanced) and Belconnen, North Canberra, and South Canberra (started). Data were obtained from excavations for the Googong pipeline between Campbell and Fyshwick, where the Narrabundah Ashstone and the Fyshwick Gravel were exposed. Excavation at Acton for the Molonglo Parkway exposed an unconformity, with the Camp Hill Sandstone overlying the Pittman Formation. Other excavations mapped included the Gungahlin No. 1 Reservoir and Stromlo-Higgins pipeline. Field mapping was carried out in the Red Hill area, on the Ainslie-Majura Ridge, and in an area south of Mount Jerrabomberra adjacent to the Googong pipeline.

Soil stratigraphic studies

Weathering surfaces in the Albury-Wodonga area were described and sampled for possible paleomagnetic dating. Soil cores from the initial inves-

tigation were reinterpreted with Dr D.C. van Dijk (CSIRO Division of Soils), giving a sounder basis for the stratigraphic classification of soils of the area.

Soil sequences were investigated in the Lanyon basins and on the Mount Jerrabomberra pediment. At Lanyon several exposures were dug, sampled, and photographed; it is intended to use Lanyon as the type area for soils developed on acid volcanics. The main aspects which are being pursued are the mineralogy of the clays and the determination of field criteria for recognition of unique diagenetic macro-features of each of the colluvial-alluvial layers on which the soils are developed, as an aid to field correlation of soil sequences.

COURSES AND CONFERENCES

by

E.G. Wilson

E.G. Wilson attended the annual Institution of Engineers Australia Conference in Cooma in March, the AWRC meeting in Adelaide in May, and the ANZAAS Congress in Melbourne in August. G. Jacobson organised the workshop meeting of Government Engineering Geologists in Canberra in November 1976, and reported on the meeting in the BMR Journal. D.C. Purcell attended the 1976 ANCOLD Conference in New Zealand in December 1976. P.D. Hohnen attended a seminar on leachate monitoring at the NSW Pollution Control Authority in Sydney in November 1976. R.C.M. Goldsmith attended the AMF Engineering Site Investigation Course in Adelaide in March 1977. J.R. Kellett attended the AWRC Groundwater Modelling Seminar in Sydney in April 1977.

MUESUM AND TRANSIT ROOM

by

D.H. McColl

Staff: D.H. McColl - Mineralogist/Curator
G.D. Nolan - Transit Officer - resigned February 1977
J.D. Reid - Technical Assistant/Cataloguer
M.S. Amar - Acting Transit Officer - since 20 May 1977
J.D. Price - Trainee Technical Officer - December 1976 to July 1977
S. Schmidt - Trainee Technical Officer - December 1976 to July 1977

MUSEUM

Collections

The major acquisition this year was the suite of highly perfect and unique malachite-cerussite-pyromorphite crystal aggregates collected during July at Brown's Deposit near Rum Jungle in Northern Territory, which is recorded in more detail under research activities.

A very fine donation of historical specimens from central Australia was received in June from Mr and Mrs D. Boerner of Alice Springs. These include the now scarce beryl and mica-feldspar crystal groups from the classical pegmatite sites in the Harts Range, meteorite fragments from Henbury and Box Hole with associated meteorite shale and explosion products. In all there are 31 specimens in this collection having a total estimated value of $1500. These samples, as in the case of previous donations, are held on behalf of the National Museums Section of the Department of Administrative Services.

Some excellent pieces were also acquired for the collections by exchange and purchase. Notable among these were three pieces of leaf gold in matrix from the Fraser Mine at Southern Cross, WA, a suite of over 100 rare and unusual mineral specimens from sites in Greenland from the Copenhagen Museum, a large showy boulder opal for display from Quilpie in Queensland, and an array of metallic and other ores from sundry areas

in NSW from Dr I. Matthias of the Canberra College of Advanced Education. Exchanges initiated overseas during the 1976 IGC are still proceeding and have provided very useful additions to our reference collections.

The Latz mineral collection which was donated last year has now been completely catalogued and coded for computerised data storage. Some unusual species, such as cuproaustinite, were identified among these specimens, which are now represented for the first time in our reference collections.

Revision and recataloguing of the R.W. Doo mineral collection of about 2500 specimens purchased in 1962, which has been proceeding intermittently for two years now, is still incomplete.

Research and external services

Museum-originated research has virtually been confined to a single project this year, the investigation of the secondary mineralisation of the Brown's copper-lead-zinc deposit near Rum Jungle in Northern Territory. There are several unique features of this occurrence which deserve a detailed publication, preferably with coloured illustrations of the distinctive habits of the metal carbonates. The occurrence of copper phosphate and arsenate mineralisation at an old prospect in the Cobar district has also been investigated intermittently. Other research projects are awaiting attention as opportunity permits.

Minor petrological, petrographic, mineralogical, and gemmological problems were also examined for the public, government departments, and BMR personnel. These ranged from casual telephone enquiries through to complex mineral chemistry investigations in liaison with universities or other BMR groups. There is a demand for a museum information service in the Canberra area, which tends to promote itself by hearsay when the service is made available.

The main related institutions variously assisted during the year include the Australian National University, Canberra Technical and Further Education College, Canberra Gem Society, British High Commission, The Australian Museum, CSIRO Mineral Sciences Division, American Embassy,

and Queanbeyan Rotary. Assistance given to Dr W. Mayer of the Canberra College of Advanced Education resulted in publication of an illustrated text on Australian mineralogy and petrology. Earth science advisory services continue to be rendered as required to the National Museums Section of the Department of Administrative Services, and in gemmological matters mainly to the Consumer Affairs Bureau.

Exhibitions

In November 1976 BMR provided a display of the geology, gems, and mineral resources of Australia for the Cairns Centenary Celebration. This was held in the newly-built Cairns Civic Centre and was associated with a lunar display of the Apollo Missions by the American Embassy. Attendance by the public was estimated at near 8000 people.

In April a special display of South Australian copper minerals derived from the newly donated Latz Mineral Collection, was put on show at the national convention of amateur geological enthusiasts, "Gemboree 1977", held at Shepparton, Victoria. J. Price represented BMR at this function, and attended the associated field excursions, collecting some useful specimens around the Shepparton district. An audience of 4000 convention participants and estimated 6000 members of the public saw the display.

A display of metallic minerals derived from the 1975 donation by Mr Colin Chidley was our exhibit at the 3rd National Exhibition of Minerals held at Glen Waverley, in Victoria, during August. This exhibition has become the leading Australian forum for mineral curators, collectors, and dealers to display new acquisitions and discoveries.

By request of the Department of Information Services, a special display of Australian ores and minerals was prepared and sent for long-term exhibition at the Commonwealth Institute in London.

A special display of some of the choicest pieces from the Latz collection was put on show for a four-week period in Parliament House during August and September. During the latter part of this period Mr Latz died in Adelaide.

The showcases especially prepared for the IGC in 1976 were installed in one of the foyers in BMR.

Educational services

Organised visits by classes of school children are still catered for by the museum, and as a newer development we have escorted some school groups on systematic visits to local regions of geological interest when requested. Sets of rocks and minerals suited to the High School curricula are provided free of charge on formal request and have been much sought after; sixteen sets were supplied. A day was spent sorting and systematising the collections at Catholic Girls High School, Griffith, and a special set was prepared for use by Dr C. Ollier, of ANU, in an Australian Development Aid Bureau project in Fiji.

For the first time this year an official request for educational services was received from the ACT Education Authority through the Departmental Secretary. Formerly such services were provided on an unofficial individual request basis.

Visitors

Present staff and facilities limit the extent that we advertise the museum services we provide for tourists and the general public of the Canberra region, but every effort is made to fill a demand which is not satisfiable from any other source. Enquiries received cover a very wide range, coming from professionals to casual members of the public. Educational requirements are the dominant source of enquiries, but visitors wishing to view the mineral collections and sundry gemmological determinations are also prominent.

The visitors' book records 658 signatures which is a considerable increase over last year, but still does not include school children in escorted classes of which there were some hundreds, or enquiries from BMR personnel. The total number of visitors in the period under review was probably about 1500. The year was notable for the record attendance of 122 visitors during the holiday season in January.

TRANSIT ROOM

Samples collected by survey parties requiring petrological, petrographic, chemical, radio-isotope, or other investigations are arranged through contractors or relevant Bureau laboratories by the transit officer (Miss M. Amar).

The total number of samples processed this year was as follows:

Thin section preparations	-	3460
Polished section preparations	-	2
Polished thin section preparations	-	152
Age determinations (various)	-	153
Chemical analyses (various)	-	4321
Sundries - Palaeontological, XRD, etc.	-	102
Total		8190

While this number of samples processed is an increase over the 6637 of 1976 it is still markedly less than the 10041 of 1975, owing to the same economic restraints. In addition to the above, 377 thin section preparations are awaiting funding.

MAP EDITING AND COMPILATION

by

G.W. D'Addario

Staff : G.W. D'Addario, W.D. Palfreyman, D.E. Gardner (retired 26 July), J. Mitchell (from 14 October 1976), N. Knight (from September 1977), J.M. Bultitude.

Advice was given to various authors and draftsmen on aspects of map and reference compilation in the preliminary and coloured series maps.

The final draft of the Standard Geological Symbols booklet was distributed to all State Geological Surveys in May. Amendments were received from some of the State Surveys and the booklet is now almost ready for printing.

MAP EDITING

Twenty-three maps were edited:

1:250 000 Geological Series - colour edition - 16 maps: South Lake Woods, Ryan, Aitape-Vanimo, Bogia, Admiralty Islands, Wilson, Percival, Sepik, Sahara, Mornington-Cape Van Diemen, Ural, Westmoreland, Lander River, Green Swamp Well, Tabletop, and Kikori.

1:100 000 Geological Series - colour edition - 2 maps: Tantangara and Brindabella.

1:10 million Maps for BMR Earth Science Atlas and other Publications - 3 maps: Main Rock Types, Cainozoic and Weathering showing thicknesses, and Surface Drainage and Continental Margin.

1:500 000 Geological Map - 1 map: The Granites-Tanami.

1:1 million Continental Shelf Sediments - 1 map: Central and Southern N.S.W. Shelf.

Editing of one map was in progress at the end of the period under review.

MAP COMPILATION

BMR EARTH SCIENCE ATLAS

The series will provide a valuable first reference to, and overview of, the geology and geophysics of Australia for schools, geologists,

overseas visitors and private and government organisations (including Australian overseas diplomatic and trade offices). The following map sheets for the Atlas are in progress; all are at scale 1:10 million.

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

This is the first sheet of the Atlas; it will probably also be included in the 3rd series of the Atlas of Australian Resources by the Division of National Mapping.

Alterations and additions were carried out and the map represents the most up-to-date geological map of Australia. The map will be edited in November 1977.

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

Cainozoic rocks, other than major sequences, are omitted, giving as far as possible, a portrayal of the bedrock geology of Australia. Fair drawing of the map is in progress.

Cainozoic and Weathering showing thicknesses - Australia (G.W. D'Addario, W.D. Palfreyman, J.M. Bultitude)

Fair drawing of this map is in progress. The map shows the main Cainozoic depositional areas and basalt, with thickness in metres; and the main areas of ferruginous and aluminous duricrust, exposed mottled and pallid zone material, and part kaolinised country rock. Selected depths of weathering, in metres, are shown by numerals.

Surface Drainage and Continental Margin - Australia (G.W D'Addario, W.D. Palfreyman, J. Mitchell, with contributions by Marine and Gravity Sections, Geological and Geophysical Branches)

This map shows areas of direct and indirect external and internal drainage, areas of disrupted drainage and areas without surface drainage. The compilation also includes submarine canyons and some palaeodrainage. It will be edited before the end of 1977.

Major Structural Units - Australia (G.W. D'Addario, W.D. Palfreyman, J.M. Bultitude)

This map shows structural units grouped under: exposed craton, and cratonic cover and basins. Subsurface basin and sub-basin boundaries are shown wherever possible.

The map will be edited before the end of 1977.

Tectonic Sketch Map - Australia (K.A. Plumb)

Compilation is completed.

Main Rock Types - Australia

This map shows igneous and sedimentary rocks, and unconsolidated sediments. Metamorphosed sedimentary and volcanic rocks are subdivided into low-grade, and medium and high-grade, metamorphic rocks. Sand and laterite, which cover about 90% of the igneous and metamorphic rocks in south-western Australia, are not shown.

The map is being fair-drawn.

Mineral Occurrences maps - Australia: Metals (N.D. Knight)

Guidelines were outlined. Size of occurrences is to be classified according to known production and reserves. Large resources will be taken into consideration. Offshore mineral occurrences are to be shown provided they meet the criteria determined for onshore occurrences.

All Australian nickel and arsenic deposits were tabulated for processing by the flat-bed plotter. It is hoped that the use of the computer will greatly simplify the compilation of the map.

CIRCUM-PACIFIC MAP PROJECT - SW QUADRANT

The Circum Pacific Map project covers more than half the world and involves scientists from 31 countries, several international organisations, and from research institutions and private organisations

throughout the Pacific region. This is an international effort to compile, evaluate, and interpret the available information concerning the geological conditions and resources of the Pacific Basin and adjacent continental areas. It will be produced in 4 series of 1:10 000 000 maps (bathymetry, geology, tectonics, resources) covering each of the 4 quadrants, plus Antarctica and a summary sheet at 1:20 000 000.

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

The Bureau is at present committed to produce a compilation of the geology of the continent and adjoining islands incorporating the latest available data. Compilation is nearly completed.

ATLAS OF AUSTRALIAN RESOURCES, 3rd SERIES

Geology of Australia 1:5 million

Compilation is in progress and is expected to be completed by February 1978. Work is done in conjunction with the other geological maps of Australia at present in hand as the same basic information is used for all the maps.

OTHER

A reference was compiled for the Rum Jungle 1:100 000 geological map, preliminary edition, and the map was checked.

NOTES TO ACCOMPANY MAPS

Notes are generally written as the map is compiled, and are in progress for several of the maps listed above. Further work was done on the drafts of Bulletins 180 and 181 which are the explanatory notes for the 1:2.5 million geological maps of the Northern Territory and Australia, published in 1976. Several text-figures were produced.

A card-based bibliography of Australian geology was prepared.

INDEXES, TECHNICAL FILES, AND MINERAL REPORTS

by

P.D. Hohnen & N.D. Knight

Staff: K. Modrak, N.D. Knight, L. Kay, M.D. Tacon (resigned 8 March), P.D. Hohnen (from 25 August), P.H. Vanden Broek (part time, November), D. Pfister (13 December to 25 March), A.P. Langworthy (part time from 7 December), P. Stuart-Smith (part time 7 December to 11 February).

STRATIGRAPHIC INDEX

Australian geoscience literature received through the Bureau library was indexed under the headings - stratigraphic name, author, 1:250 000 Sheet area, basin name, and subject (using terminology compatible with the AMF Thesaurus). Copies of author, Sheet area, and subject cards were given to the Bureau library. Various combinations of duplicate cards were sent out from time to time to the State Geological Surveys and cards for literature indexed according to sedimentary basins were passed to the Bureau's Basin Assessment Group.

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 indexes. Seven hundred and seventy-five new names, including proposed names (which were reserved), and definitions were indexed. About 100 approved definition cards for proposed stratigraphic units were indexed as received from Stratigraphic Nomenclature Sub-committees of the Geological Society of Australia.

Bi-monthly Variations Lists and the annual Deletions List, noting additions to and deletions from the Central Register, were compiled and distributed to Subcommittees of the Stratigraphic Nomenclature Committee, to State Geological Surveys, to Universities, and to mineral exploration companies.

Written and oral enquiries about stratigraphic names were dealt with.

The new convenor of the Stratigraphic Nomenclature Committee, Mr H.R.E. Staines, was briefed on the mechanics of operation of the Stratigraphic Registry, and copies of relevant files were obtained for him.

TECHNICAL FILES

Indexing of unpublished data and newspaper clippings continued until September, when Technical Files were placed on a care and maintenance basis.

MINERAL INDEX AND MINERAL REPORTS

The bibliographic index to current literature on mineral deposits (arranged by commodity and State) and a card index of major mineral deposits were maintained until August when the activity was closed down.

The mineral resources reports on antimony and molybdenum were updated and passed to the editors; they are ready to go to press. A short time was spent writing a Record on Australian arsenic occurrences.

METALLIFEROUS SECTION

Head of Section: W.B. Dallwitz

GEOLOGICAL INVESTIGATIONS IN NORTHERN TERRITORY AND ANTARCTICA

Supervising Geologist: R.G. Dodson

ARUNTA PROJECT

by

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

STAFF: R.D. Shaw (project leader), A.J. Stewart, L.A. Offe, A.P. Langworthy, R.G. Warren, L.P. Black (part time) and A.Y. Glikson (part time); B.E. Hobbs (Monash University) and M.J. Rickard (Australian National 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 basis for exploration for the region's mineral resources.

Soon after its inception, the Arunta Project evolved a two-party approach to its field research program, for two main reasons. First, the Arunta Block is geologically so complex that to concentrate field work in a single area ran the risk of expending much time and effort in obtaining a picture of the geological make-up of an atypical, non-representative part of the Block. Secondly, the large size of the Block - about 300 000 km^2 - is far too great for investigations of separate areas to be conducted efficiently from a single operational base. The decision to form two parties turned out to be fully justified, because the two areas investigated - the northwest and southeast parts of the Block - proved to be distinctly different, most importantly in the degree of structural complexity. In the southeast, multiple folding and faulting have invested the Block with a very complex geometry, whereas in the northwest the macroscopic structure is much more simple, and has allowed the decipherment of a stratigraphic sequence, which was subsequently extended to the southeast. Other differences between the two areas include lithological composition and metamorphic grade of the constituent rocks, abundance of granite, and nature of metal occurrence. In

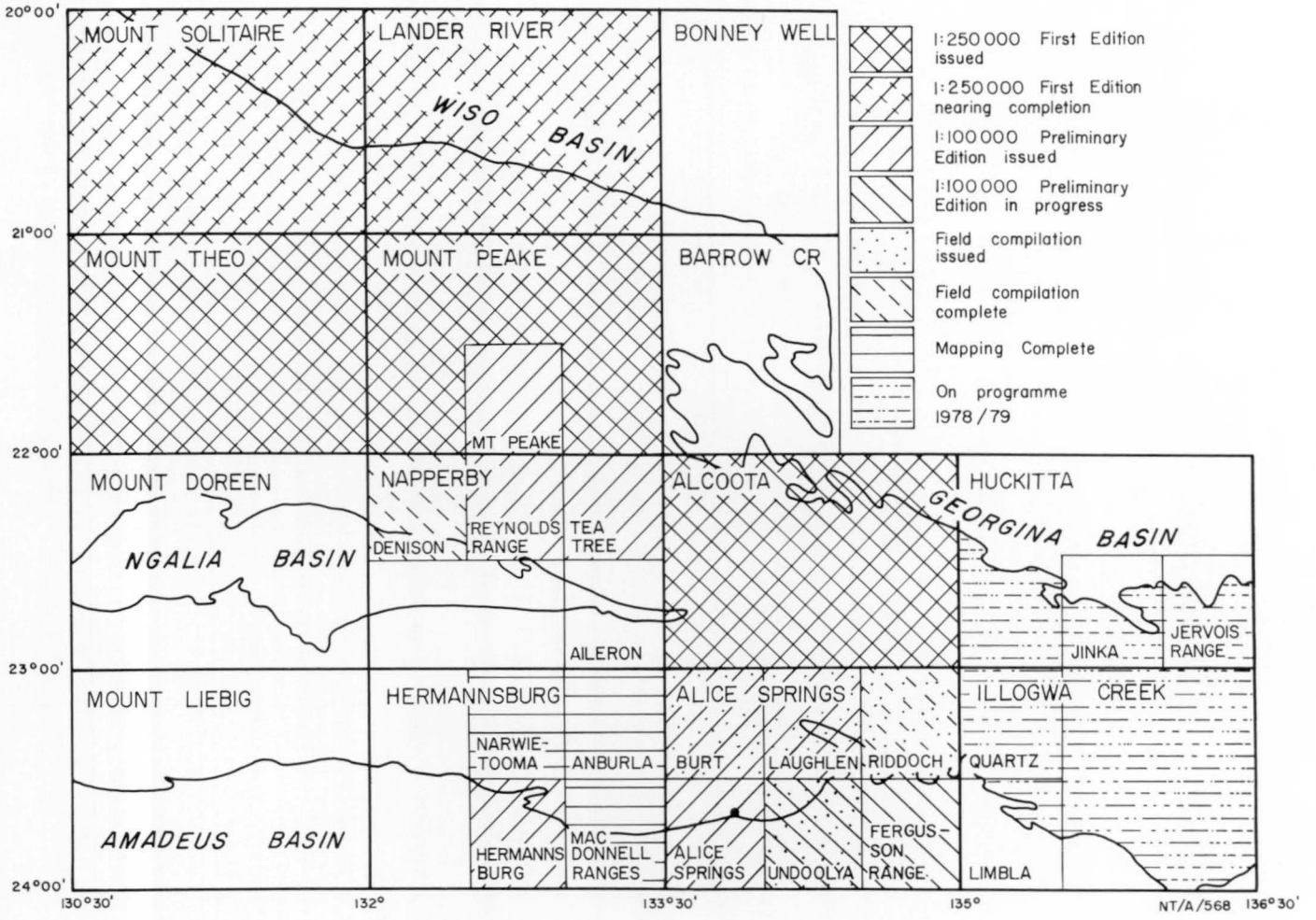


FIG.M1 Progress of geological mapping and index to 1:250 000 and 1:100 000 Sheet areas, Arunta Project

a sense, the two areas complement each other - each displays geologic and metallogenic phenomena not found in the other - and the total picture gained thereby has yielded a unified geologic and metallogenic history of the area.

The chief results of the year's work have been:

1. Publication of two First Edition 1:250 000 Geological Maps (Mount Theo, Mount Peake) and two Preliminary 1:100 000 Maps (Burt, Alice Springs). Eight other 1:100 000 maps are in various stages of production (Fig. M1), and compilation sheets (at 1:26 000) of four of these have been publicly released.
2. Publication in the BMR Journal of a paper 'The Mineral Potential of the Arunta Block' by Stewart and Warren, which amplifies a broad three-fold stratigraphic division of the Block introduced in the Annual Summary for 1975.
3. Preparation of a metamorphic map of the Arunta Block (Fig. M2), as part of the Metamorphic Map of Australia.
4. Writing of two data Records on the southeast and northwest parts of the Arunta Block continued, and was well advanced at the end of the year.

Field research has now been completed over most of the better exposed part of the Arunta Block. Future work in the less exposed areas will emphasise metallogenic studies, and interpretation of the solid geology in regions of Cainozoic cover.

DATA PRESENTATION

ALICE SPRINGS 1:250 000 SHEET AREA

Writing of the data Record continued and should be completed by the end of the year. Fifty whole rocks, mainly mafic granulites and felsic gneisses from the Strangways Metamorphic Complex (Fig. M3) have been analysed; the analyses indicated a remarkable similarity between the chemistry of many of these mafic rocks and modern-day basalts, supporting the hypothesis that there has been little migration of elements during metamorphism. The felsic gneisses are thought to represent metavolcanics and sediments derived from an acid igneous terrain. Future geochemical work will be concentrated on ore-bearing horizons in the upper part of the Strangways Metamorphic Complex.

Further chemical and isotopic investigation of the Mordor Igneous Complex has confirmed that this rock suite has affinities with both the kimberlitic and ultrapotassic series. Its unique chemistry can be explained by derivation from an atypical upper mantle source followed by chemical equilibration of the magma at an intermediate depth. We predict that kindred intrusions may be localised along major crustal features such as the Woolanga lineament. The results of the Mordor study were presented at the Annual BMR Symposium, and are the subject of a paper submitted to 'Contributions to Mineralogy and Petrology' by Langworthy and Black.

Reinterpretation of rock units in the West Bore area has drawn attention to the nature of the boundary between the Strangways Metamorphic Complex, a largely meta-igneous unit, and the overlying unnamed unit which consists of rocks interpreted as largely metasediments. Widespread retrograde metamorphism from granulite or upper amphibolite facies to lower amphibolite facies in the West Bore rocks was closely related to the subparallel West Bore Fault and the Cadney Fault Zone. These faults are major overthrusts of late Proterozoic age or younger, as the West Bore Fault affects Heavitree Quartzite.

Stewart completed photo-interpretation of parts of Riddoch, Undoolya, and Fergusson Range 1:100 000 Sheet areas. The work includes a new interpretation of the Bitter Springs Formation, which resulted in delineation of two major thrust-faults (or slides), one at the front of the Arltunga Nappe Complex, the other a few kilometres to the south below the main sequence of sedimentary rocks of the Amadeus Basin.

Burt and Laughlen 1:100 000 Sheet areas

The Preliminary Edition of Burt was issued in late 1976. A legend has been prepared for a combined Burt-Laughlen coloured 1st Edition Map.

Alice Springs 1:100 000 Sheet area

Drafting of the Preliminary Edition was completed, and the map is being printed.

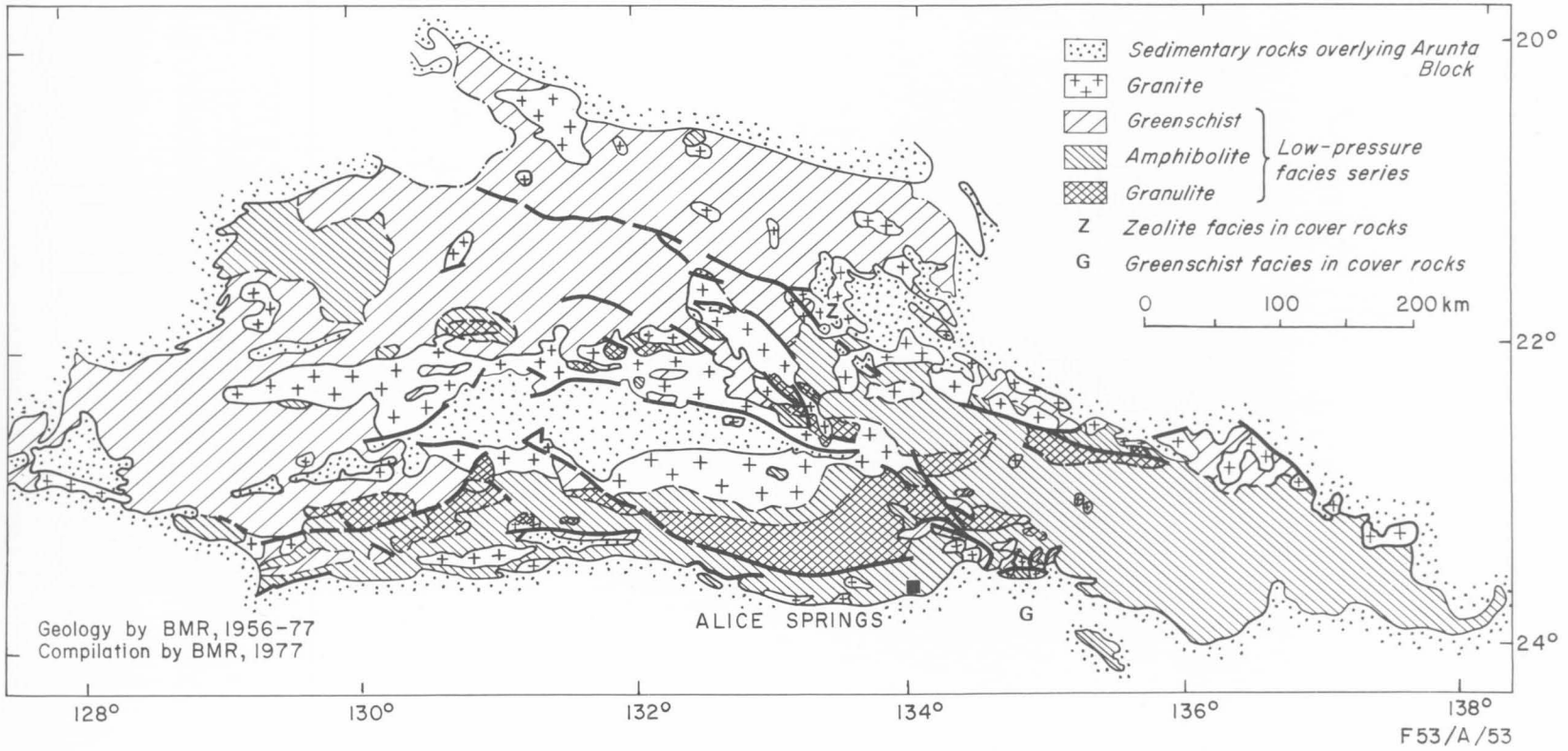


FIG.M2 Metamorphic map of Arunta Block

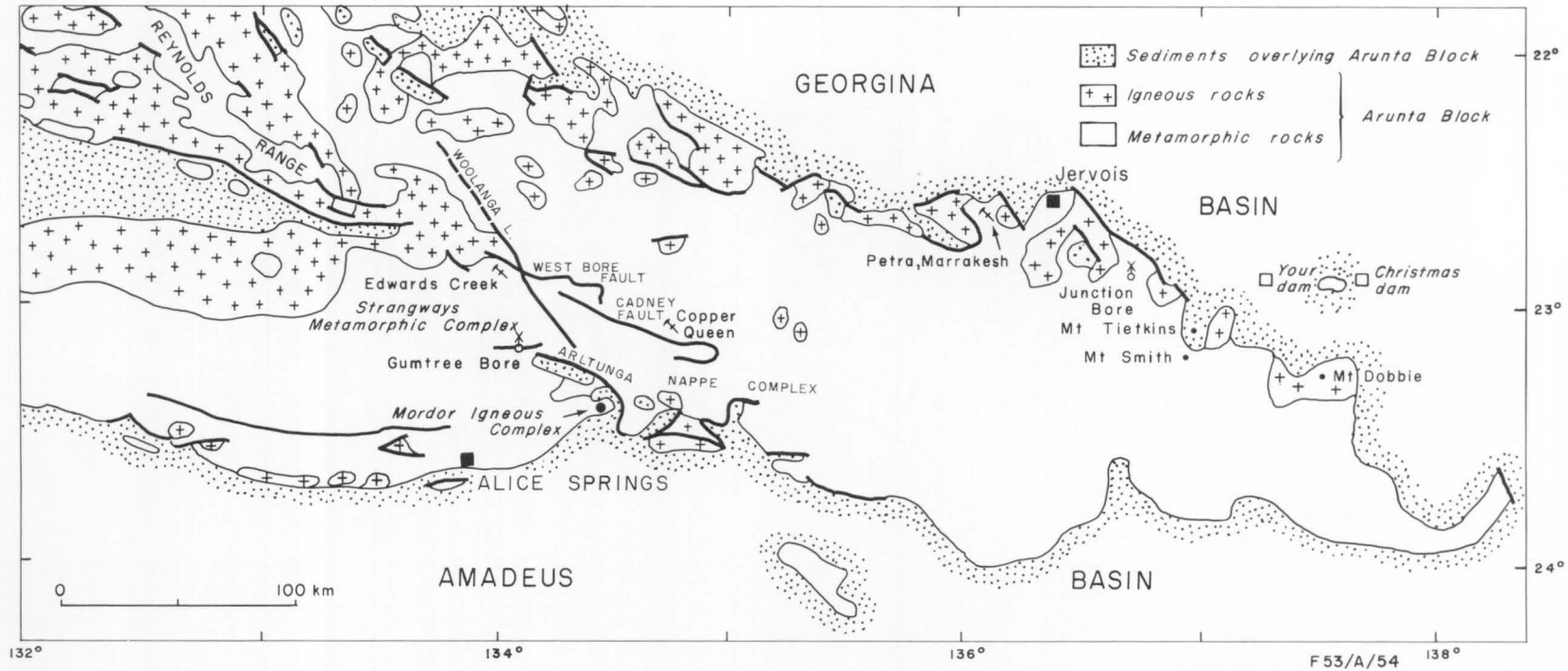


FIG.M3 Generalised geological map of southeast Arunta Block, showing localities referred to in text

Undoolya 1:100 000 Sheet area

Photo-compilation sheets were drawn and reduced, and drafting of the map is in progress.

Fergusson Range 1:100 000 Sheet area

Photo-interpretation and compilation were completed, and drafting of the map is in progress.

Riddoch 1:100 000 Sheet area

Photo-interpretation was completed, and photo-compilation at 1:26 000 scale is almost complete preparatory to reduction and drafting of the map.

HERMANNSBURG 1:250 000 SHEET AREA

MacDonnell Ranges 1:100 000 Sheet area

Preparation of photo-overlays following the 1976 field season is complete except for the eastern portion where C. Mawer (Ph. D. student, Monash University) has just completed three months' field work. His results will be incorporated before final compilation.

NAPPERBY 1:250 000 SHEET AREA

Offe completed 80 percent of his writing commitments to the data Record.

Aileron 1:100 Sheet area

New photo-overlays incorporating all contributions by previous workers were prepared, and compilation at 1:26 000 scale began.

Denison 1:100 000 Sheet area

Thin-section examination and preparation of photo-overlays were completed, and drafting of photoscale compilations has begun.

MOUNT PEAKE 1:250 000 SHEET AREA

Thin-section examination of specimens was completed for inclusion in the data Record. The First Edition of the map has been printed, and is ready for distribution. The Explanatory Notes are in press.

MOUNT THEO 1:250 000 SHEET AREA

The First Edition Map and Explanatory Notes were printed and distributed.

MOUNT SOLITAIRE 1:250 000 SHEET AREA

The First Edition (colour) of the map is being fair drawn, and the Explanatory Notes are in press.

LANDER RIVER 1:250 000 SHEET AREA

The First Edition Map is being prepared for contact drafting, and the Explanatory Notes have been written and edited ready to go to press.

MOUNT LIEBIG AND MOUNT RENNIE 1:250 000 SHEET AREAS

A Record entitled 'Ground Geophysical and Geological Investigations in the southern Arunta Complex, NT' was written by A. Mutton, P. Wilkes (Geophysical Branch) and Shaw. Rocks of granitic origin in this area show a very wide range in magnetic susceptibility after metamorphism to the upper amphibolite facies. The unmetamorphosed granites show a progressive increase in magnetic susceptibility as they become more basic. A comparison of granite suites of similar composition shows that muscovite-bearing types

tend to have lower magnetic susceptibilities than those containing only biotite which, in turn, have lower susceptibilities than hornblende-bearing varieties. Clinopyroxene-bearing granitoids have the highest susceptibilities of the granitic rocks. Remanent magnetism is a significant factor in many of the granulities and migmatites. Modelling of three north-south cross-sections and production of two solid geology maps are in progress. All field data have been catalogued in the SURFAUST system of storage and retrieval.

ARUNTA BASEMENT IN THE HAY RIVER, TOBERMORY AND MOUNT WHELAN 1:250 000 SHEET AREAS (GEORGINA BASIN PROJECT)

Warren was attached to the Georgina Basin Party to examine the basement rocks in the region covered by the project.

Two formally named granites, an informal granite unit, and several unassigned granites were delineated. The Mount Tietkens Granite Complex, cropping out south and east of Mount Tietkens, consists of an older leucocratic, even-grained phase and a younger, porphyritic phase. Both phases are cut by numerous tourmaline-muscovite-quartz-feldspar pegmatites. The Mount Dobbie Granite, cropping out as inselbergs in the Mount Dobbie district (Hay River 1:250 000 Sheet area), is an even, coarse-grained granite characterised by a high proportion of muscovite and small, irregular pegmatite segregations. The Junction Bore granite is a biotite-muscovite granite in which the biotite is extensively chloritised. Unassigned granitic rocks occur at the western edge of the Mount Whelan Sheet area, near Christmas Dam, and near Mount Smith where they antedate the Mount Tietkens Granite Complex.

In the Mount Smith area a sequence of quartzofeldspathic gneiss, two-mica schistose gneiss, and calc-silicate gneiss is extensively intruded by granite, and has been designated the Mount Smith metamorphics. The metamorphic grade of these rocks is lower amphibolite facies as both muscovite and sillimanite are present. The metamorphics are assigned to Division 2 of the Arunta Block.

East and northwest of Your Dam, a sequence of deeply weathered muscovite-feldspar-quartz gneiss and schist is exposed below dissected mesas of Tarlton Formation. No other rocks of the Arunta Block were located in contact with these metamorphic rocks, but they are overlain by Late Proterozoic units, and are tentatively assigned to Division 2 of the Arunta Block.

FIELD ACTIVITIES

Shaw and Warren conducted two Soviet scientists, A.S. Novikova and S.A. Sidorenko, on an inspection of the Arunta and Musgrave Blocks as part of a USSR/Australian scientific exchange. Dr Novikova has carried out extensive research into similar terrains in Russia, and Dr Sidorenko is an expert on carbon isotopes and their relation to mineralisation.

Shaw and Stewart participated in the BMR Inspection of Northern Australian Geology, including parts of the Arunta Block, during June and July.

Stewart and Giddings (Geophysical Branch) collected 35 metasandstone and amphibolite samples from the Lower Proterozoic Lander Rock Beds in the Reynolds Range (Fig. M3), as part of a project to try to date the time of sedimentation by palaeomagnetic means.

MINERAL RESOURCES

Orientation stream sediment geochemistry in the Huckitta 1:250 000 Sheet area

Dispersion trains in stream sediments were studied at two separate prospects using analyses of minus-80 fraction. Downstream from the Petra deposit, copper values fell to background levels over about 200 m, at a distance where the stream still contained malachite-stained cobbles. Similarly, at the Marrakesh prospect tungsten values fell abruptly to background in less than 300 m. Coarse scheelite fragments can be detected by ultra-violet light in the same creek 100 m downstream from the prospect. An unexpected increase in tungsten values 800 m downstream from the Marrakesh prospect may indicate an additional unidentified source. Both samplings confirmed the result of an earlier investigation in the Edwards Creek area, and indicated the restricted value of standard stream sediment geochemical surveys in this semi-arid terrain.

Rare minerals from the Arunta Block

Specimens of geikielite and kornerupine were collected near the Copper Queen prospect, Mount Riddoch 1:100 000 Sheet area and identified by G. Barnes (BMR). Geikielite, not previously reported in Australia, is a magnesium-ferrous iron-titanium structural analogue of ilmenite. Kornerupine,

a borosilicate of magnesium, iron, and aluminium, is currently known to occur at only four localities in Australia, all within the Arunta Block. The minerals occur in association with coarse-grained sapphirine, cordierite, sillimanite, tourmaline, potash feldspar, plagioclase, phlogopite, and enstatite. One large rounded pebble of geikielite was collected together with a number of fragments of kornerupine up to 3 cm across.

Further work is planned to determine the properties and chemistry of these specimens, and to obtain more specimens from the locality.

ISOTOPIC STUDIES

Black's results for this year are presented in the report of the Geochronological Laboratory in this Record.

MISCELLANEOUS ACTIVITIES

Shaw and Stewart prepared comments on the suitability of the Gumtree Bore in central Australia, which has been suggested as a site for storage of nuclear waste. Stewart attended the New South Wales Geological Survey Symposium on 26 May. Langworthy spent about one month assisting the Stratigraphic Index Section.

DARWIN OFFICE

by

C.E. Prichard

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

Staffing was further reduced during the year and the store/workshop is not manned.

Departmental stores staff from Canberra arranged issue of stores for 1977 parties from stocks held and disposed of remaining stock. There is now no

operating store but room is available for field parties to deposit stores between field seasons.

Field parties in the area left most of their vehicles at the Darwin store after the 1976 season. Some of the vehicles were auctioned; replacements were delivered to Darwin and held for the 1977 season. The drill party used workshop facilities to service their drill and vehicles before the 1977 season.

At the store/workshop remaining cyclone damage has been repaired and the buildings upgraded to post-cyclone standards. Missing ceilings have been replaced in the Wood Street Office but the building has not yet been properly repaired or upgraded to the post-cyclone code.

Reference facilities have been popular with all sectors of the general public, students, and mining industry throughout the year. Sale of geological maps increased and averaged over seventy per month. The Senior Geologist gave a talk on Geological History of the Top End to the matriculation class of a secondary school; many students have sought source material and discussions.

The Group staff have provided assistance to several Bureau operations such as the delivery of explosives to the marine survey vessels Valdivia and Vema, and advice and assistance regarding entry to various restricted areas, e.g. Wild Life Sanctuaries and Aboriginal Reserves. Transport and traverse camping equipment was provided for a number of visiting Bureau officers.

The landline from Manton Seismic vault which had been destroyed by Cyclone Tracy was replaced, enabling the recorders to be moved from Manton and re-installed in the Darwin Office. The seismic station has been maintained in operation throughout the year with but minor loss of record.

PINE CREEK GEOSYNCLINE PROJECT

by

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

STAFF: R.S. Needham (project leader), I.H. Crick, P.G. Stuart-Smith, M. Roarty (NT Mines Branch)

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 1:250 000 scale geological maps of the region.

The Alligator Rivers and Rum Jungle Parties combined this year to form the Pine Creek Party to complete mapping of the central part of the Pine Creek Geosyncline. To date fourteen 1:100 000 Sheet areas have been covered with field observations. During 1977 emphasis has been on completion of field work in the Mundogie 1:100 000 Sheet area, preparation of preliminary 1:100 000 Sheets, detailed examination of the stratigraphy of Golden Dyke and Koolpin Formations, and preparation of a paper describing the Oenpelli Dolerite. Field work continued in the Tipperary 1:100 000 Sheet area, with G.C. Lau of NT Mines Branch mapping the Palaeozoic sediments of the Daly River Basin. Next year, field work will be in the McKinlay River, Mary River, and Tipperary Sheet areas.

REPORTING

Progress of map production is shown in the frontispiece maps and in Figure M4. The Cahill, Gilruth, and Field Island 1:100 000 Preliminary maps were issued during the year; final drafting of the Kapalga, Jim Jim, Howship, Oenpelli, Batchelor, and the Rum Jungle Special 1:100 000 Preliminary maps is in progress. A Bulletin describing the Alligator Rivers Uranium Field is in preparation, and Explanatory Notes will be written to accompany the First Edition 1:100 000 Sheets. Records describing the 1974 drilling results in the Alligator Rivers region and 1975 drilling results in the Burnside Granite area were issued. A paper describing the Cahill Formation was published in the BMR Journal. A Record describing 1974-6 drilling results in the Kapalga Sheet area has been drafted, and a paper describing deformation structures in the Kombolgie Formation has been accepted for external publication in 'Sedimentology'. Members of the party participated in a workshop on the Pine Creek Geosyncline, held concurrently with the 1977 BMR Symposium. Needham presented a paper on the regional setting of the uranium deposits in the Pine Creek Geosyncline to the Second Australian Geological Convention in February.

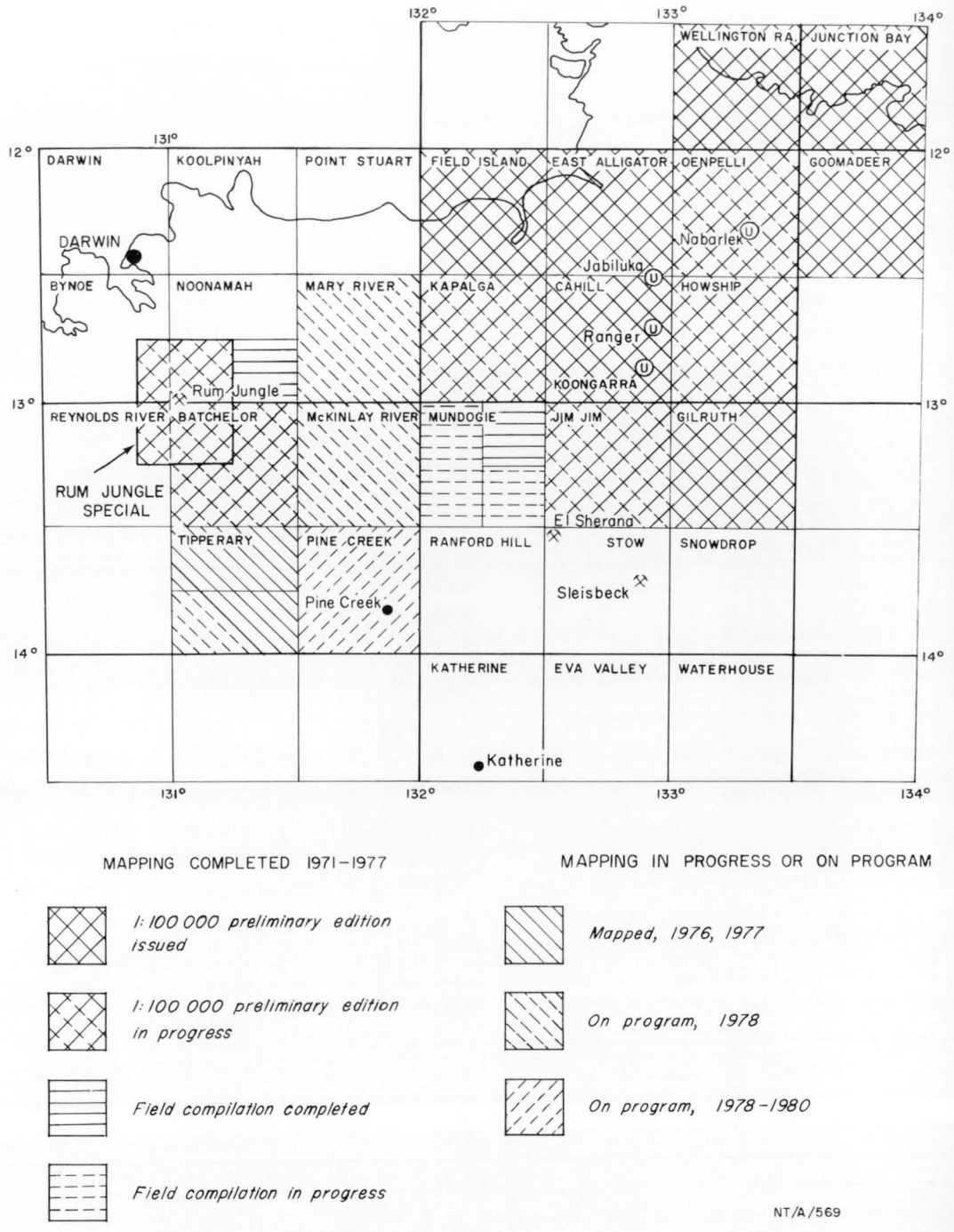


FIG.M4 Progress of geological mapping and index to 1:100 000 Sheet areas, Pine Creek Geosyncline Project

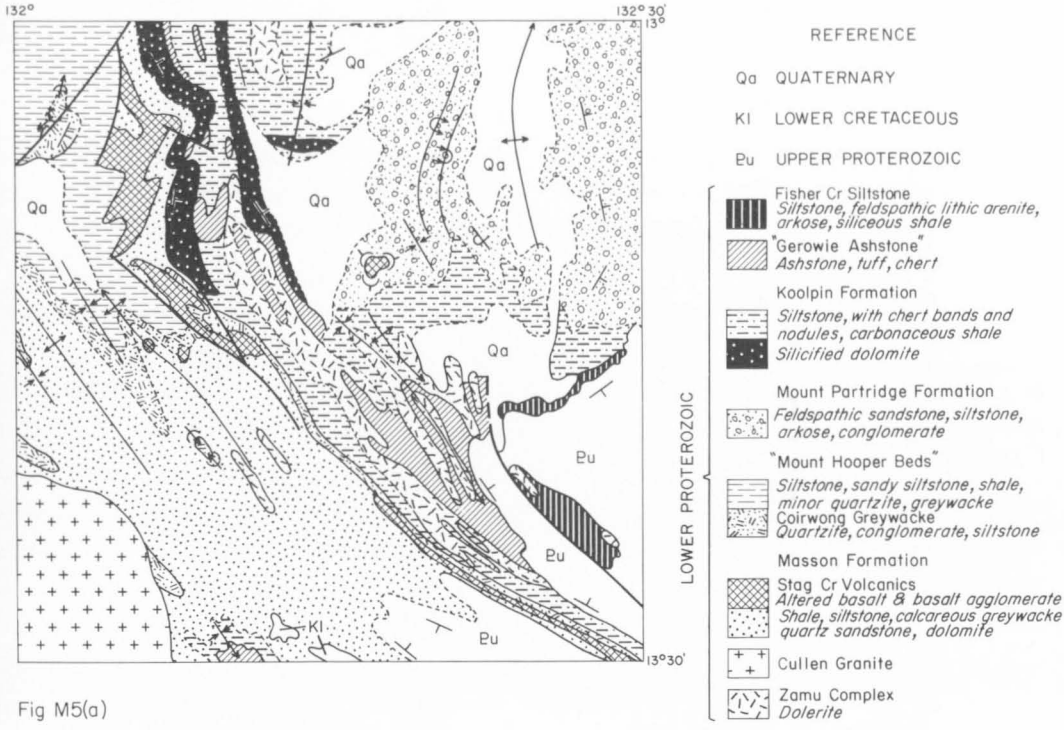


Fig M5(a)

FIG.M5(a) Generalised geology of Mundogie 1:100 000 Sheet area

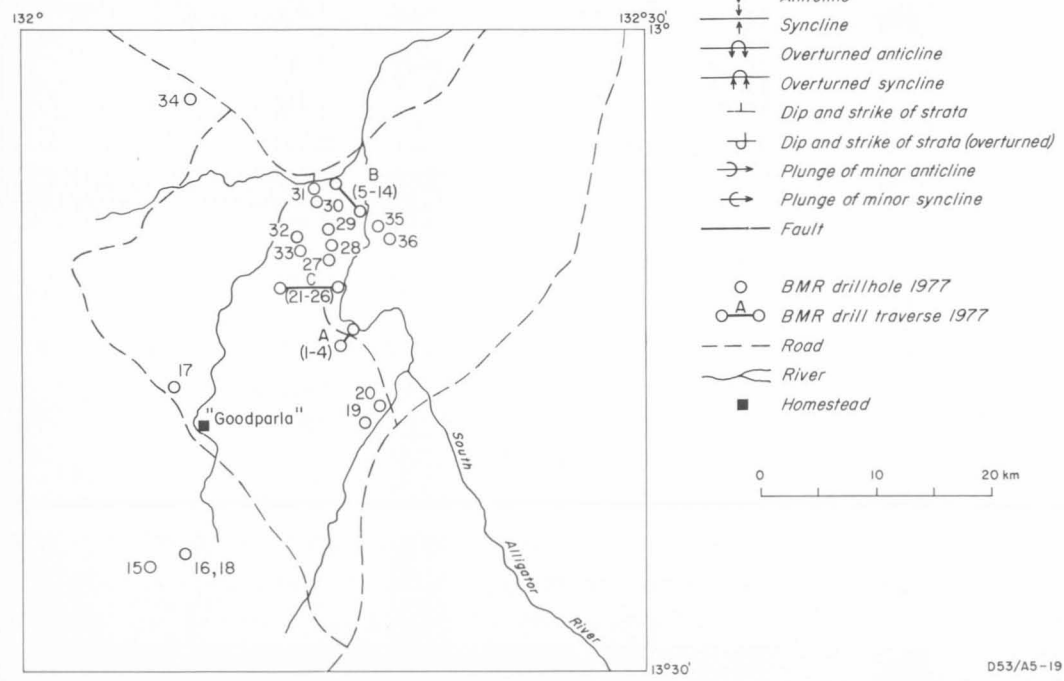


Fig M5(b)

FIG. M5(b) Drill hole locations Mundogie 1:100 000 Sheet area

MUNDOGIE SHEET AREA

The southern half of the Mundogie 1:100 000 Sheet area was field surveyed during 1977 and field checking was completed throughout the northern half. Mapping has resulted in significant changes to published maps of the area; in particular, the distribution and stratigraphy of the Masson and Koolpin Formations on the Mount Evelyn 1:250 000 Sheet require modification (Fig. M5 a).

The Koolpin Formation consists of an interbedded sequence of dolomite, siltstone, and volcanogenic sediments. Coarse and fine-grained dolerite of the Zamu Complex forms extensive sills in the sequence, and these are folded with the sediments about subhorizontal fold axes.

In the northeast of the Sheet area, the base of the Koolpin Formation is marked by a sandy dolomite breccia which grades southwards into more massive silicified dolomite with spherical and columnar algal structures. In the central and southeastern parts of the Sheet area these rock types are absent and the base of the Formation is marked by massive chert-banded ferruginous siltstone. This is overlain by an interbedded sequence of tuff, ashstone, chert-banded and nodular siltstone, and ferruginous siltstone. Tuff and ashstone are predominant towards the top of the Koolpin Formation and attain a maximum thickness in excess of 700 m near Shovel Billabong. Previously the ashstone and tuff, which is at present informally referred to as the 'Gerowie Ashtone', were mapped as Gerowie Chert and as part of the Fisher Creek Siltstone.

In the extreme south of the Sheet area nodular and chert-banded siltstone and ashstone form a south-plunging syncline unconformably overlying the Masson Formation. The sequence, mapped previously as the Golden Dyke Formation, is identical to the Koolpin Formation/'Gerowie Ashstone' sequence of the South Alligator Valley and is therefore correlated with it.

The eastern extent of the 'Gerowie Ashstone' is terminated by a north-striking high-angle reverse fault about 6.5 km east of Shovel Billabong. East of this fault, metasiltstone, feldspathic sandstone, phyllite, greywacke and arkose of the Fisher Creek Siltstone, and dolerite of the Zamu Complex, are exposed along the base of the escarpment to near the southern end of the Mount Partridge Range, and in an inlier in the Kombolgie Formation to the south. The relation between the Fisher Creek Siltstone and the Koolpin Formation is concealed by scree, but appears to be unconformable.

The Coirwong Greywacke is continuous with similar prominent outcrops of feldspathic quartzite and conglomerate, previously mapped as part of the Masson Formation, north of the Goodparla Homestead. The sequence is intensely faulted and folded about northwest-trending axes, and has an overall westerly regional strike. In the extreme northwest of the Sheet area the Coirwong Greywacke is exposed in the core of a small dome and is surrounded by colour-banded sandy siltstone, shale, quartz sandstone, and quartz greywacke. This sequence is continuous northwards into the Kapalga Sheet area where it has been mapped as the 'Mount Hooper Beds'. A correlation between the 'Mount Hooper Beds', Coirwong Greywacke, and the Mount Partridge Formation is probable, considering their similar composition, and their unconformable relationship with the underlying Masson Formation and interbedded Stag Creek Volcanics.

Formal subdivision of the Masson Formation has not been attempted, but a broad two-fold stratigraphic sequence is recognised: a basal unit composed of mainly porous quartz sandstone with calcareous greywacke, limestone, quartzite and minor siltstone and shale; and an upper unit consisting mainly of siltstone and shale with minor quartzite and calcareous greywacke. The pelitic rocks are commonly carbonaceous, but are ubiquitously altered at surface to hematite siltstone. Exposures of carbonaceous rocks are confined to the hornfels zone around the Cullen Granite.

Field investigations have confirmed that the Stag Creek Volcanics is interbedded with the topmost part of the upper unit of the Masson Formation, and is much more extensive than previously mapped. The unit includes altered basaltic agglomerates, basalt, flow top breccia, tuff, and dark green shales.

In the southwestern corner of the Sheet area, shale of the Masson Formation commonly contains chiastolite where it has been metamorphosed by the Cullen Granite. Two of the five phases of the granite described by Walpole (1968) are present in the Mundogie Sheet area.

REGIONAL CORRELATIONS

Correlations between the Golden Dyke Formation, Koolpin Formation, and Gerowie Chert

The Golden Dyke Formation in the Burnside Granite area is divisible into five units which can be correlated with similar units in the Rum Jungle

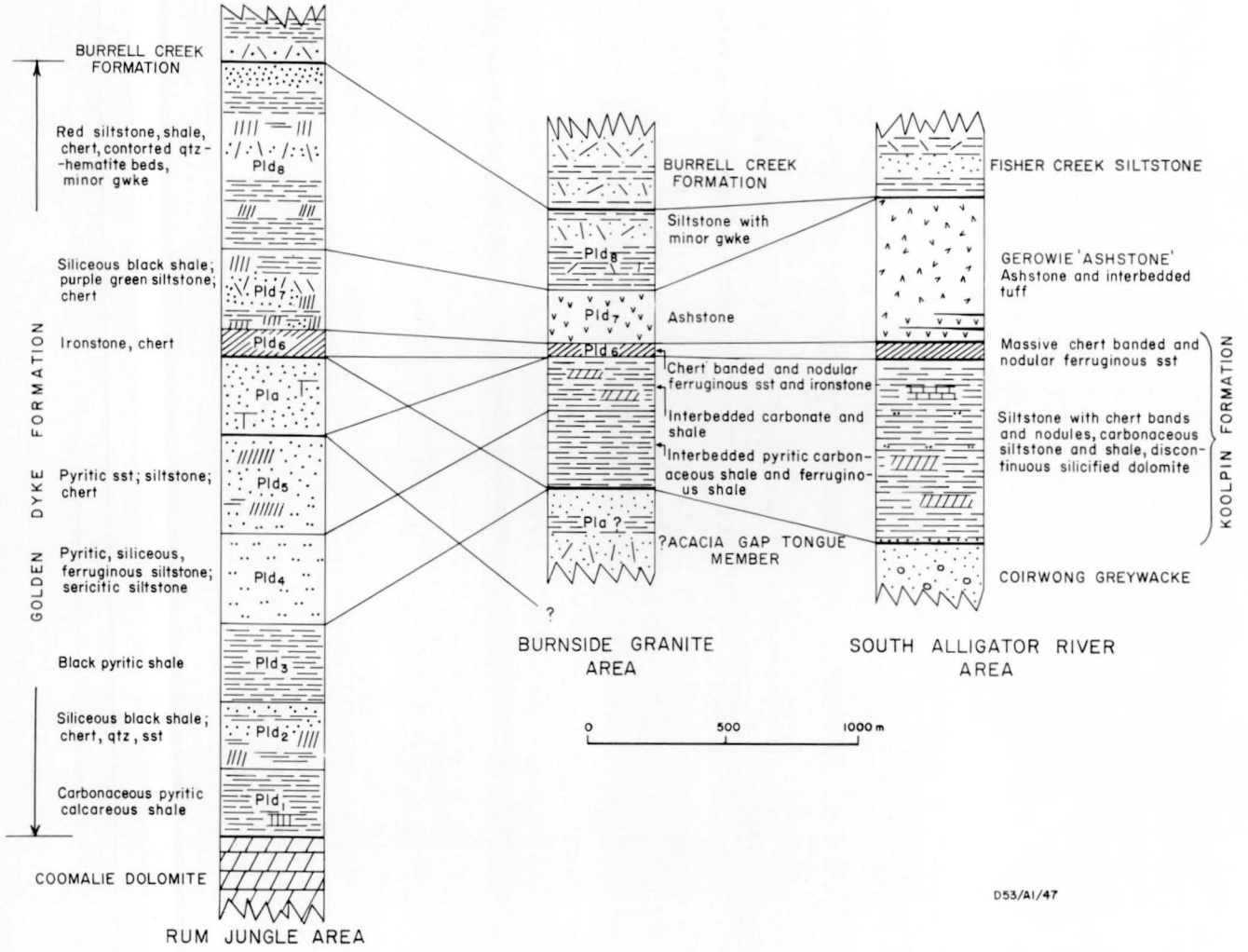


FIG.M6 Stratigraphic correlation of some Early Proterozoic units, Rum Jungle to the South Alligator River area

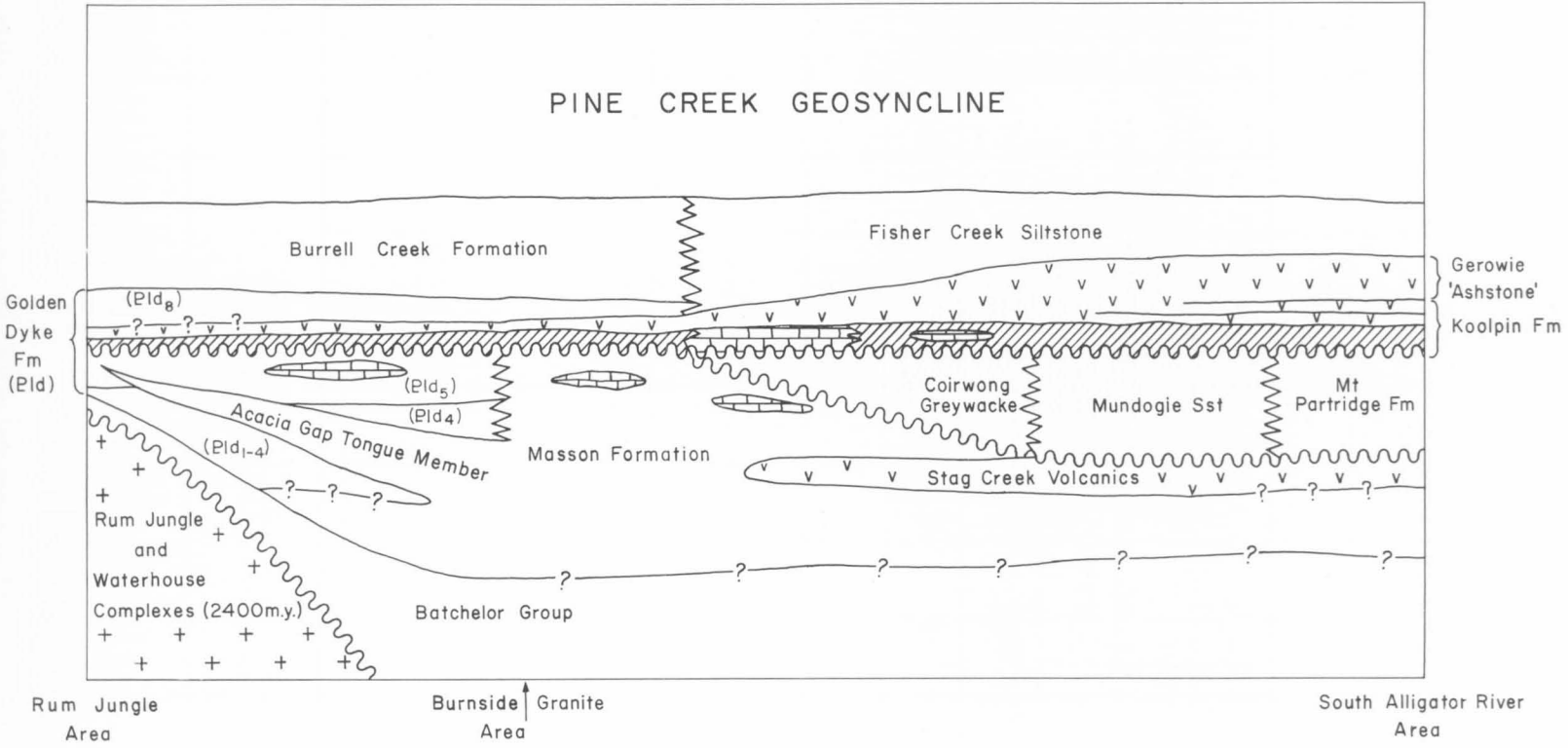


FIG.M7 Early Proterozoic rock relationship diagram, west and central Pine Creek Geosyncline

area (Fig. M6). The most distinctive unit in this correlation is a chert-banded and nodular ferruginous siltstone and ironstone (Pld_6; Fig. 5 a). This unit is very similar to the basal part of the Koolpin Formation in the central and southeastern parts of the Mundogie Sheet area (Fig. 7).

Petrological examination of a dark grey chert which directly overlies the ironstone in the Golden Dyke Formation in the Burnside Granite area showed it to be an ashstone consisting of 10% quartz, and K and Na feldspar crystal fragments often elongated and sometimes curved (i.e. eutaxitic texture) in a fine-grained recrystallised cherty matrix. Similar examination of thinly bedded, black cherty rock and spotted green chert from the Gerowie Chert revealed they are volcanogenic. The black cherty rock consists of fine-grained angular curved and elongate fragments of quartz and feldspar in a very fine-grained granoblastic groundmass of quartz, alkali feldspar, and sodic plagioclase. The green spotted chert is similar in composition but is coarser and more feldspathic. Preferential weathering of the feldspar fragments gives the rock a spotted appearance.

The ash-fall genesis of the volcanic rocks indicates a time-rock correlation. As the ashstone unit is conformable regionally with other units in the Golden Dyke and Koolpin Formations, it appears that the five-fold correlation proposed is similarly time-rock, and not time-transgressive as proposed by Walpole et al. (1968).

Correlation of the Koolpin and Cahill Formations

Since the completion of the drilling program in the Kapalga 1:100 000 Sheet area during 1976, pebbles of silicified dolomite have been identified in conglomerate of the 'Mount Hooper Beds'. They provide the only direct evidence of the relative ages of the Koolpin and Cahill Formations. As the Koolpin Formation is known to overlie the correlatives of the 'Mount Hooper Beds' in the Mundogie 1:100 000 Sheet area, the pebbles were probably derived from the Cahill Formation which contains massive dolomite in the area.

Rather than being a lateral and time equivalent of the Koolpin Formation, the Cahill Formation is an older unit, possibly a correlative of the Batchelor Group. No definite stratigraphic relation between the two formations can be drawn until the stratigraphy above the Cahill Formation is known in more detail.

DRILLING

Forty shallow rotary and diamond-drill holes were completed in the Mundogie Sheet area during 1977 (Fig. M56). The objectives of the drilling were to test airborne and ground geophysical anomalies obtained from a concurrent geophysical program in the area, and to identify bedrock in areas of poor outcrop.

Drilling and ground geophysical surveys in the Buffalo Creek Plains area showed that shale, phyllite, and quartzite of the Mount Partridge Formation extend across most of the plain, and that siltstone of the Koolpin Formation which forms the West Alligator Syncline is not continuous with the Koolpin Formation 'Gerowie Ashstone' sequence of the South Alligator Valley. Rather they are interpreted as forming a younger sequence which onlaps the Mount Partridge Formation to the east.

OENPELLI DOLERITE

Geochemical and petrographic studies of the Oenpelli Dolerite show that olivine is more common than previously recognised, and is a normative phase of the ophitic dolerite that forms the bulk of the intrusion. The following differentiation sequence is recognised: Olivine basalt → porphyritic olivine dolerite → olivine dolerite (ophitic dolerite) → quartz dolerite (or gabbro) → granophyre.

Results of chemical analyses show that the dolerite is a near-saturated tholeiite, not an alkaline intrusive as was thought previously.

DIAMOND-DRILL HOLE INTO CAHILL FORMATION

A second attempt by NT Mines Branch to drill into Cahill Formation exposed in a road cutting 11.6 km east of the South Alligator River bridge, along the Arnhem Highway, is in progress. The hole is designed to reach a depth of 500 m and sample the diverse stratigraphy exposed in the cutting.

TIPPERARY SHEET AREA by G.C. Lau (NT Mines Branch)

Field work continued in the southern half of the Sheet area. About 75 percent of the Sheet area has been completed.

The southern half of this area contains scattered outcrop, found mainly in water courses, of carbonate, sandstone, shale, and siltstone of the Daly River Group.

The Group has previously been divided into three formations: the Tindall Limestone, Jinduckin Formation, and Oolloo Limestone. The Tindall Limestone is Middle Cambrian, and the boundary between Cambrian and Ordovician strata appears to be within the Jinduckin Formation.

Subdivision of the Tindall Limestone into a basal arkosic unit, one or more fossiliferous crystalline carbonates, and a red-brown mudstone unit near the top, appears possible. Intraformational breccia occurs within this Formation on the eastern side of the Sheet area. A buff, aphanitic limestone on the western side contains in places previously unrecorded barite and fluorite with traces of sphalerite, pyrite, and galena. This indicates that carbonates within the Tindall Limestone may be host to Mississippi Valley type ores.

Within the Jinduckin Formation, a brown, very fine-grained quartz sandstone forms a marker bed which can be traced on both sides of the basin axis.

Field checking of the Oolloo Limestone has so far shown that the main rock type is a grey, oolitic dolomite, which is glauconitic in part.

RUM JUNGLE DISTRICT 1:100 000 SPECIAL SHEET

by

R.G. Dodson

Drafting of the Rum Jungle District 1:100 000 special sheet is about 95 percent complete; revision of the Reference has delayed completion of the drafting.

TENNANT CREEK

by

R.G. Dodson

The Record on the geology of the Tennant Creek area was reviewed by the section head and returned to the supervisor for attention. The Explanatory Notes and 1:250 000 First Edition map have been sent to the printer.

ANTARCTICA

by

J.W. Sheraton

STAFF: R.J. Tingey, J.W. Sheraton, L.A. Offe, D.J. Ellis
(only Tingey full-time)

INTRODUCTION

Systematic field research involving 1:250 000 scale mapping of rock outcrop in Australian Antarctic Territory continues, the major emphasis at present being in Enderby Land. The main object is to provide basic geological information about this relatively little-studied area, in particular its economic potential. BMR geological work in Antarctica, in cooperation with the Antarctic Division of the Department of Science, is part of a much wider program of scientific work involving a range of disciplines.

Four BMR geologists (Tingey, Sheraton, Offe, and Ellis) were seconded to the Australian National Antarctic Research Expedition (ANARE) for the 1977 summer field operations in Enderby Land. The major priority for the season was geological and geophysical fieldwork, and the generally favourable weather was an important factor in ensuring the successful completion of the program. The availability of almost complete colour vertical airphotos, which had been flown the previous year, was a considerable advantage over previous seasons. All significant outcrops in Enderby Land and a number in Kemp Land were visited and

detailed petrographic and geochemical study was carried out. It is intended to undertake sampling for geochronology during the 1978 field season. When base maps become available, the preparation of 1:250 000 geological sheets will commence. On the return voyage to Australia a brief visit was made to Gaussberg in Wilhelm II Land. Gaussberg is an isolated extinct volcano of leucite basalt, which was sampled for petrographic, geochemical, and geochronological investigation. Details of some of these studies are given in the report on the work of the Petrological Laboratory.

A Record by Sheraton and Offe describing the results of the 1976 field season in Enderby Land was completed. Tingey attended the 3rd Symposium on Antarctic Geology and Geophysics, held in Madison, Wisconsin, and presented three papers: 'The geology of the Prince Charles Mountains, Antarctica' (Tingey), 'Origin of charnockitic rocks of MacRobertson Land' (Sheraton), and 'A gravity survey of Enderby and Kemp Lands, Antarctica' (P. Wellman and Tingey). Details of the first two of these papers were given in the Geological Branch Summary of Activities for 1976 (BMR Report 196). After the symposium, Tingey travelled to the United Kingdom where he will spend a year on study leave at the Scott Polar Research Institute, Cambridge.

GEOLOGY OF ENDERBY LAND

The exposed rocks of Enderby Land and the adjacent part of Kemp Land comprise a high-grade metamorphic complex intruded by a range of felsic and mafic igneous rocks. The highest grade of metamorphism reached in the rocks of central Enderby Land was medium-pressure granulite facies, although in western Kemp Land the high pressure assemblage garnet + clinopyroxene + quartz occurs in mafic granulites. It was during this metamorphism that the present foliation, largely defined by a compositional layering, was formed. Mesoperthite is a characteristic mineral in these gneisses and is compatable with crystallisation under high temperatures and low water pressures. The presence of coexisting sapphirine and quartz in certain aluminous metasediments indicates temperatures of at least $800^{o}C$ and possibly as high as $1050^{o}C$. The granulite facies rocks are intruded by several types of dolerite dyke, as well as metamorphosed mafic to ultramafic dykes and, in a few areas, large granitic bodies. Comparison with similar dolerites in the Vestfold Hills, Princess Elizabeth Land, which have been dated at about 1400 m.y., and in the southern Prince Charles Mountains suggests that the early high-grade metamorphism is of Early

Proterozoic or Archean age, although there are not yet sufficient geochronological data to confirm this. Two unusual alkali basalt dykes, consisting mainly of feldspar, biotite, alkali amphibole, and apatite were found at one locality where they cross-cut a fresh dolerite dyke.

Elsewhere, notably in the western part of Enderby Land and in the Nye Mountains, the metamorphic grade is rather lower - upper amphibolite to lower granulite facies. Hydrous minerals (hornblende and biotite) are much more abundant, pyroxenes are less common, mesoperthite is absent except as porphyroclasts in some rocks, and there are numerous pegmatite and granite veins. Fresh dolerite dykes appear to be absent, although the deformed and metamorphosed mafic dykes which occur at a few localities are probably the equivalents of the dolerites of central Enderby Land. If this is the case, then the gneisses of this area include reworked material of the older high-grade complex, although the presence of major deformed and metamorphosed suggests that younger rocks may also be present. Localised medium to high-pressure upper amphibolite facies metamorphism in post-dyke shear zones in central Enderby Land are attributed to this younder metamorphic event. A Rb/Sr isochron age of 987 $\pm$ 60 m.y. obtained on charnockitic gneiss from the area of the Soviet base at Molodezhnaya in western Enderby Land (Grew, 1975, Antarctic Journal of the United States, 10, 245-248) suggests correlation with the granulite-facies rocks of the northern Prince Charles Mountains and MacRobertson and Kemp Land Coast which form part of a Late Proterozoic (900 to 1100 m.y.) mobile belt.

Late-stage retrogression (greenschist or amphibolite facies) was associated with the emplacement of granite and pegmatite veins, particularly in western Enderby Land. The pegmatites have been dated at about 500 m.y.

A tentative summary of the geological history of Enderby Land is given below.

1. Deposition of sediments, including pelitic, siliceous, and ferruginous types, and probable extrusion of mainly acid volcanics.
2. Emplacement of mafic and ultramafic dykes and possibly granitic intrusions.

3.	Medium-pressure (locally high-pressure) granulite-facies metamorphism; formation of present foliation and isoclinal folds.	?Archaean or Early Proterozoic
4.	Major asymmetric folding, with localised retrogression.	
5.	Intrusion of dolerite dykes.	
6.	Upper amphibolite to lower granulite-facies metamorphism with associated asymmetric folding in western Enderby Land and the Nye Mountains, probably contemporaneous with localised high-pressure metamorphism in shear zones elsewhere in Enderby Land.	?900-1100 m.y.
7.	Low-grade retrogression, mylonite zones, epidote veins and pseudotachylite, probably associated in part with granite and pegmatite intrusion.	500 m.y.
8.	?Intrusion of alkali basalt dykes.	

GEOLOGICAL INVESTIGATIONS IN QUEENSLAND AND PAPUA NEW GUINEA

Supervising Geologist: K.R. Walker

MOUNT ISA-CLONCURRY PROJECT

by

G.M. Derrick

STAFF: BMR : G.M. Derrick (Project leader), R.M. Hill; GSQ : I.H. Wilson

The aim of the project is to carefully 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 are geochronology and geochemistry (see Metalliferous Laboratories report), Duchess geology and Lawn Hill geology (see below).

FIELD ACTIVITIES

ALSACE 1:100 000 SHEET AREA

Introduction

The field research in the Alsace Sheet area was completed using 36 hours of helicopter traversing and some vehicle traversing during July and

August 1977. The results generally support the reconnaissance geological framework described in the 1976 Annual Summary, that is, the geology is dominated by a central north-trending belt 10-15 km wide of basement granite and acid volcanics, the Ewen block, which is flanked to the east and west by parallel belts 10-20 km wide of younger sedimentary and basaltic rocks of the western succession. A wedge of the Kalkadoon-Leichhardt basement block occupies the southeastern quarter of the Sheet area, in association with thin basal sediments of the eastern succession. Geology and stratigraphy of the Sheet area are summarised in Figures M8 and M9.

The most significant modifications to the 1976 reconnaissance and features of the 1977 mapping, are as follows:

1. Possible presence of Leichhardt Metamorphics in the Ewen block.
2. Presence of volcanic stratigraphy in the Argylla Formation.
3. Andalusite schist and other higher-grade metamorphic rocks along Surprise Creek, together with arkose and interbedded quartz-ironstone rock.
4. More accurate definition of Eastern Creek Volcanics and Myally Subgroup basin margins.
5. Occurrence of possible halite casts in the upper redbed sequence of the Myally Subgroup, and recognition of a new zone of colonial stromatolites.
6. Redefinition of the Surprise Creek Beds into, from the base, the Quilalar Formation (4 units), Surprise Creek Formation (4 units), and Mount Isa Group (2 units).
7. Elucidation of facies changes, particularly in Quilalar Formation, to show topography on the depositional shelf, and distribution of redbed sandstone-siltstone sequences across the Sheet area.
8. Recognition of Fiery Creek Volcanics resting unconformably between the Quilalar and Surprise Creek Formations.
9. Variations in the nature of the unconformity at the base of the Surprise Creek Formation, and recognition of local conglomeratic channel fill, grading upwards into a transgressive sequence containing fine turbidites, carbonaceous shale, and persistent but very low-grade copper mineralisation.

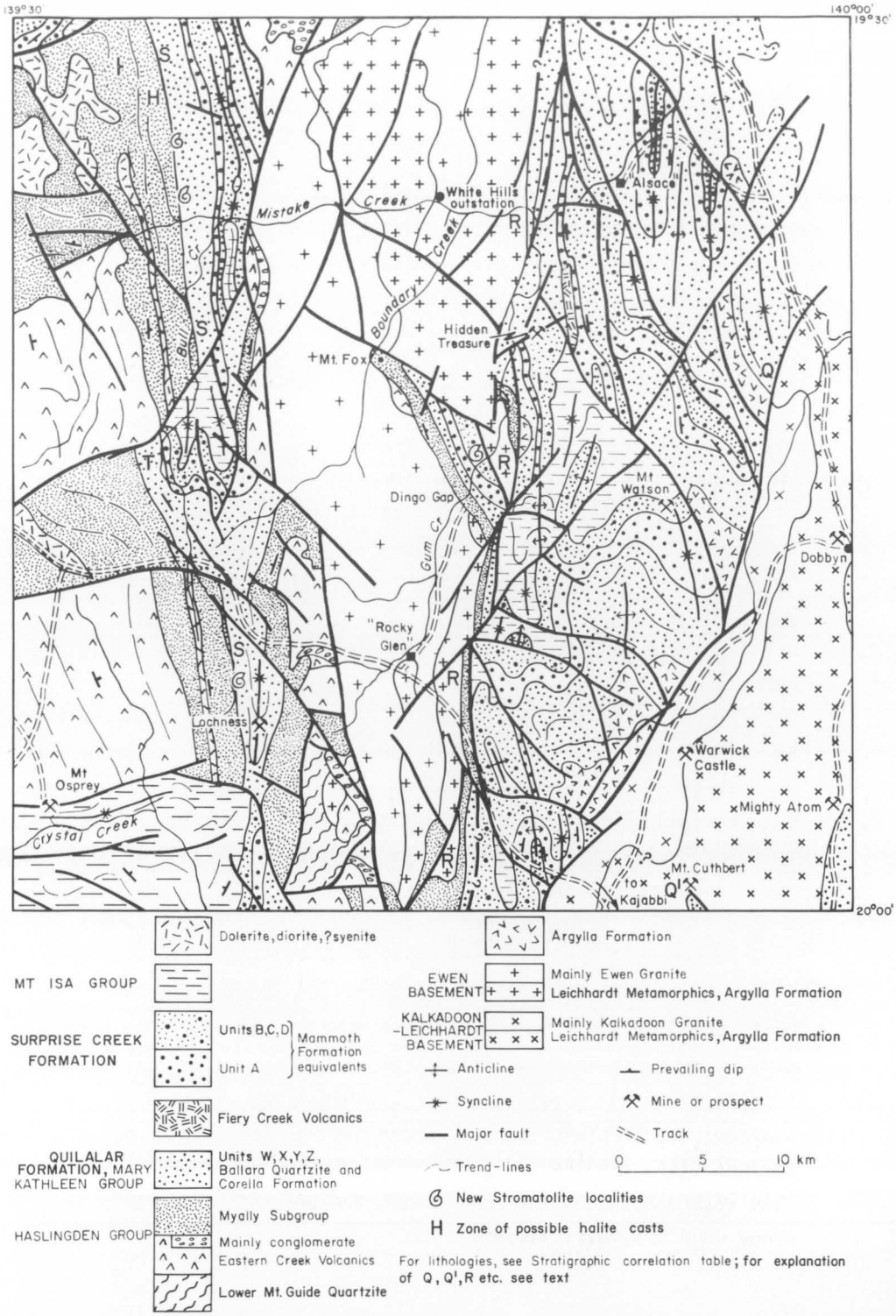
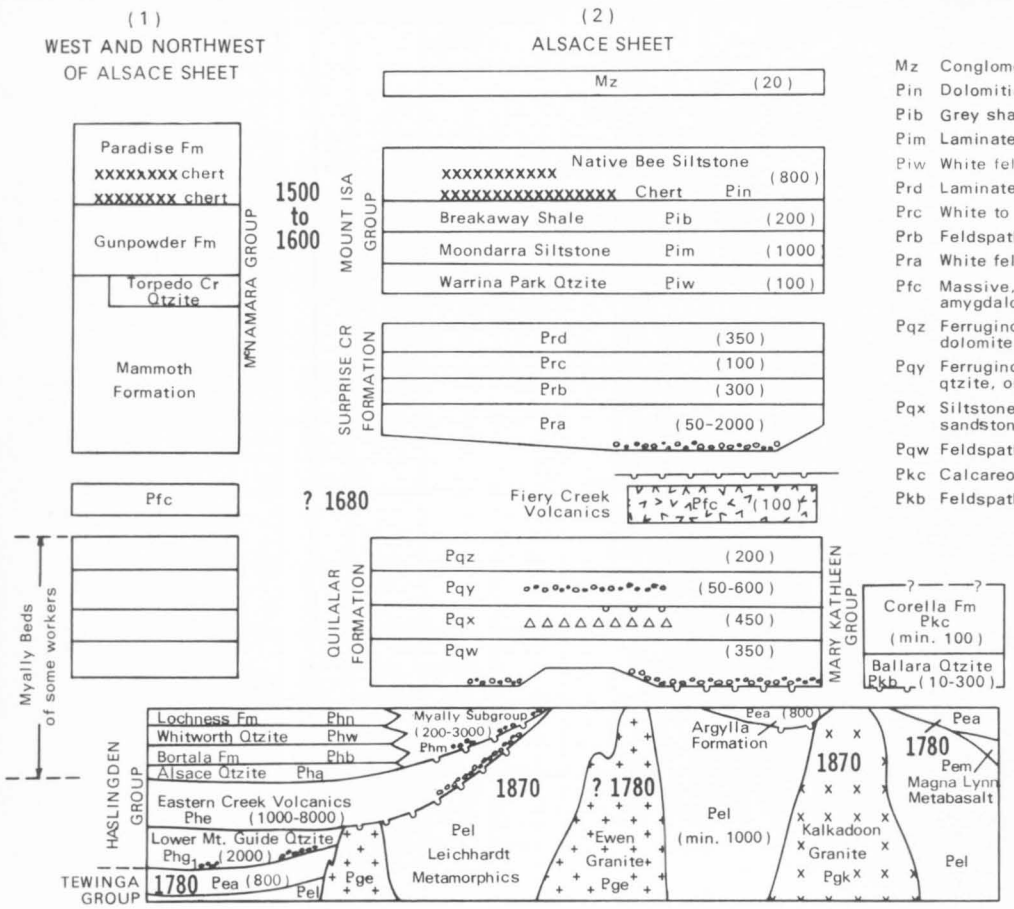


FIG. M8 General geology, Alsace 1:100 000 Sheet Area



Mz Conglomerate, feldspathic and quartzose sandstone, siliceous shale

Pin Dolomitic siltstone, dolomite, chert, algal chert

Pib Grey shale and siltstone

Pim Laminated siltstone, f.g. sandstone, micaceous sandstone

Piw White feldspathic qtzite, orthoqtzite, minor grey siltstone

Prd Laminated siltstone, carbonaceous siltstone, flaggy fine sandstone

Prc White to brown feldspathic qtzite, ferruginous qtzite, grey–green siltstone

Prb Feldspathic f.g. sandstone, siltstone

Pra White feldspathic qtzite, pyritic qtzite, conglomerate

Pfc Massive, earthy hematitic metabasalt, scoriaceous metabasalt, amygdaloidal metabasalt, feldspathic, ferruginous qtzite

Pqz Ferruginous sandstone and siltstone, clay pellet conglomerate, dolomite, micaceous siltstone, feldspathic qtzite with shale clasts

Pqy Ferruginous sandstone, feldspathic sandstone with pebbles, clayey qtzite, orthoqtzite, feldspathic qtzite

Pqx Siltstone with sand pillows, purple shale, siltstone, dolomite, ferruginous sandstone, qtzite, intraformational breccia, algal dolomite

Pqw Feldspathic qtzite, orthoqtzite, arkose, conglomerate, ferruginous sandstone

Pkc Calcareous siltstone, calc-silicate rocks, qtzite, para-amphibolite

Pkb Feldspathic sandstone, qtzite, conglomerate

Phm Feldspathic clayey qtzite, arkose, grit, conglomerate, ferruginous siltstone, with ? halite casts

Phe Metabasalt, conglomerate, feldspathic qtzite and orthoqtzite, arkose, purple siltstone, dolomitic siltstone

Phg_1 Psammitic schist, andalusite schist, chloritic tuff, arkose, conglomerate, quartz-iron fmn, metabasalt, quartz greywacke, acid volcanics

Pem Metabasalt, chlorite schist, quartzite

Pea Crystal tuff, porphyry, metabasalt, ashstone, quartzite

Pel Grey & pink porphyry, tuff, spherulitic rhyolite, gneiss

Pge c to m.g. granite, leucogranite, granodiorite, pegmatite, aplite

Pgk c.g. granite, granodiorite, aplite

Note

(a) Figures such as 1780 refer to age in m.y., inferred from similar or equivalent units to south

(b) Numbers in parentheses refer to average thickness or thickness range for units, in metres

M(S)/464

FIG. M9. Stratigraphy, correlations and lithology of units, Alsace 1:100 000 Sheet area

More detailed comments on some of these items follow.

Stratigraphy and lithology

The volcanics in the Ewen block, formerly Argylla Formation, are now tentatively assigned to the Leichhardt Metamorphics (Figs. M8 & M9). Apart from abundant grey to pink quartz-feldspar porphyry, ignimbrite, and crystal tuff, the unit also contains some flow-banded rhyolite, spherulitic rhyolite, and amygdaloidal andesite. Layering east of White Hills outstation trends northwest, and may young northeastwards. Along the eastern margin of the Ewen block the unit is overlain unconformably by Myally Subgroup and Quilalar Formation. In the southeast of the Sheet area the volcanics are of higher metamorphic grade than in the Ewen block, and are overlain by remnants of the Magna Lynn Metabasalt.

The Argylla Formation, apparently confined to the eastern half of the Sheet area, is a thin but well layered sequence of about four ignimbritic rhyolitic sheets with intercalated amygdaloidal metabasalt, glassy quartzite, and labile sediments. Thin remnants of Argylla Formation may be present along the eastern edge of the Ewen block (zone R Fig. M8). In places the absence of the Magna Lynn Metabasalt marker makes separation of the Argylla Formation and Leichhardt Metamorphics difficult, and some chemical work is planned to help with this problem.

Ewen Granite intrudes the ?Leichhardt Metamorphics, and is more extensive than shown on the Dobbyn 1:250 000 Sheet. A fine to medium-grained granite is the most abundant rock type, but granodiorite and coarse porphyritic biotite granite are present near Rocky Glen. Northwest of Mount Fox a gradation exists between porphyritic volcanics, porphyritic microgranite, and fine to medium granite; this suggests that the Ewen Granite may be comagmatic with ?Leichhardt Metamorphics, and hence about 1870 m.y. old, which contrasts with the currently quoted Rb/Sr age of 1780 m.y. However, a younger age for Ewen Granite may also be a possibility since it intrudes a sequence of andalusite schist, phyllite, mica schist, micaceous greywacke, chloritic tuff, and metabasalt, 5 to 10 km southeast of Lochness prospect; this relatively high-grade sequence appears to overlie acid volcanics (possibly Argylla Formation), and may be equivalent to the lower Mount Guide or Leander Quartzite succession. It

appears to be overlain unconformably by quartzite and conglomerate of the Lena Quartzite Member of the Eastern Creek Volcanics, and is also associated with a sequence of arkose and quartz-iron formation bands along Surprise Creek. The granite phase in this area thus appears to antedate Eastern Creek Volcanics, but may postdate lower Mount Guide Quartzite equivalents. Work on this problem is continuing.

Eastern Creek Volcanics display the usual three-fold division in regular sequences north of Crystal Creek, but the unit thins rapidly to the east, where thick lenses of conglomerate are intercalated with metabasalt and siltstone. Clasts include acid volcanics (resembling those of the Ewen/Kalkadoon blocks), quartzite, and concretionary purple siltstone; the latter suggests a period of weathering before deposition. The greywacke matrix commonly contains carbonate cement. Some basic volcanics, possibly Eastern Creek Volcanics, were located near Mount Fox.

The four-fold division of the Myally Subgroup was maintained throughout the Alsace Sheet area, but, like the underlying Eastern Creek Volcanics the Subgroup thins rapidly eastwards, to a sequence of clayey feldspathic quartzite and basal arkose and conglomerate near Zone R (Fig. M8).

East and west of the Ewen block units W, X, Y and Z of the Quilalar Formation were mapped, although the sequences in each area are not always directly comparable. Unit W, mainly variably ferruginous and feldspathic sandstone, is apparently conformable on the Myally Subgroup in the west, possibly disconformable on ?Myally Subgroup near Zone R (Fig. M8), and unconformable on Argylla Formation in the east. A tentative correlation may be possible between W and the Ballara Quartzite in the eastern succession, at points Q and Q' (Fig. M8). Unit X contains algal dolomite in the west, and ferruginous silt, shale, dolomitic silt and sand in the east, where ?intraformational ferruginous breccias are also widespread. Unit Y, a mainly arenaceous facies, contains more mature quartzose sands in the west than in the east, where pebbly feldspathic sandstone is common. The latter is locally unconformable on unit X 10 km ESE of Rocky Glen. Unit Z displays variable thickness because of overlap by younger units; ferruginous and dolomitic siltstone and sandstone are abundant, and mudflake conglomerate is characteristic. Just east of Hidden Treasure prospect the Fiery Creek Volcanics overlie unit Z with apparent conformity, and can be related lithologically and stratigraphi-

cally to the type area in the Seymour River area, about 90 km to the WNW. They represent a period of volcanicity between the Quilalar Formation and the unconformably overlying Surprise Creek Formation (Units A, B, C, and D), which appears to be a transgressive sequence fining upwards from sandstone and conglomerate to siltstone and shale. Unit A is a prominent, hard white feldspathic quartzite which thins markedly along Zone R (Fig. M8). East of this zone it contains thick lenses of conglomerate at the base; similarly, in the west, in the Bull Creek belt, the basal sequence is locally a ferruginous brown conglomerate, overlying Unit Z conformably.

The Warrina Park Quartzite, the basal unit of the Mount Isa Group, is a hard white feldspathic quartzite, commonly copper-stained, which together with the overlying Moondarra Siltstone is useful for correlation purposes throughout the region. Marker chert beds of the Native Bee Siltstone are present in the Crystal Creek sequence, and thin conglomerate beds are present in the Moondarra Siltstone in the Bull Creek belt.

Palaeogeography and depositional environments

Apart from possible deeper-water sands in the lower Myally Subgroup, and graded, distal turbidite deposits in unit D of the Surprise Creek Formation and Mount Isa Group, the presence of various crossbedding types, bevelled ripple marks, abundant iron oxide, arkosic regoliths, channel deposits, and stromatolites all suggest persistence of shallow-water conditions throughout most of the stratigraphic column. Hydroplastic(?) structures (convoluted bedding, ball-and-pillow structures) are also widespread, and may form in both shallow and deeper-water environments.

Eastwards thinning accompanied by an increase in the proportion of conglomerate in the Eastern Creek Volcanics and Myally Subgroup suggests a basin margin may have existed near zone R (Fig. M8). Possible halite casts near zone H (Fig. M8) indicate evaporative or very shallow-water conditions prevailed at the top of the Myally Subgroup in the Bull Creek belt; newly discovered colonial stromatolites (columns 1-2 cm diameter in beds 10 cm thick) at the top of unit W, (zone S, Fig. M8), algal beds in unit X, and marked thinning of unit Y near zone T, all indicate persistence of such conditions for a considerable

period. The thinning of units W, Y and A in the Alsace belt towards zone R, and the lithology of the Mount Fox-Dingo Gap outlier suggest that this inferred Haslingden Group basin margin possibly formed a north-trending rise which modified sedimentation across the younger Quilalar depositional shelf.

Economic geology

No mines were operating in the Alsace Sheet area in 1977, although Warwick Castle operated in 1976, and Crusader mine, just southeast of Dobbyn in the adjoining Coolullah Sheet area, was in production during 1977. These, and other mines in the Kalkadoon block, are formed in quartz-filled hornblende and biotite schist zones cutting volcanics of the Leichhardt Metamorphics. The Hidden Treasure prospect contains malachite and chalcocite-filled fractures in carbonaceous siltstone of unit D (Surprise Creek Formation), adjacent to a northeast-trending left-lateral shear; this unit and to a lesser extent the overlying quartzite and siltstone of the Mount Isa Group have been geochemically sampled by companies, and some areas, mainly in the south of the Alsace belt, have been drilled.

Some potential may exist for copper in 'redbed' and associated strata-bound environments. Throughout the stratigraphic column, arkose, quartz-ironstone rocks, ferruginous siltstone, sandstone, and dolomite are widespread; disconformities, unconformities, transgressive sequences, palaeohighs, channel fills, breccias, etc., are all present in the Sheet area and may exercise some control over metal leaching, transport, and deposition. Mineralisation at Hidden Treasure for instance occurs in a chemical reductant (carbonaceous siltstone) formed at the end of a period of transgressions, and overlies red sandstones and volcanics which thin westwards towards a possible palaeohigh (zone R, Fig. M8).

Copper mineralisation is present at Mount Osprey in a quartz-filled shear zone separating dolomitic siltstone of the Mount Isa Group from metabasalt of the Eastern Creek Volcanics; siltstone and chert of the Native Bee Siltstone at Crystal Creek have also been drilled. Some anomalous metal values are reported from the Lochness prospect, a large ridge of manganiferous ironstone formed in

unit X (Quilalar Formation) in a shear located just in the west limb of a regional syncline. Some gold is reported from the area 2-8 km northeast of Lochness.

Cu-Fe sulphides are ubiquitous in some flows of the Eastern Creek Volcanics, and in dolerite ?sills intruding Eastern Creek Volcanics and Myally Subgroup in the northwest of the Sheet area.

COOLULLAH 1:100 000 SHEET AREA

A brief reconnaissance was made of the Coolullah Sheet area. Leichhardt Metamorphics, Magna Lynn Metabasalt, Argylla Formation, Ballara Quartzite, and Corella Formation were examined. Much of the Corella Formation is highly metamorphosed calc-silicate rock which is locally migmatitic. The extensive quartzite, psammitic schist and amphibolite sequence, mapped previously in the Quamby Sheet area, extends through the central part of the Coolullah Sheet area.

GEOCHRONOLOGY

Derrick, Wilson and Hill assisted R. Page in extensive geochronological sampling throughout the region, from Duchess to Lawn Hill,including samples of Weberra Granite and Eastern Creek Volcanics for U-Pb zircon studies. Geochronological results are presented elsewhere.

INSPECTION OF NORTH AUSTRALIAN GEOLOGY

Derrick and Wilson, together with 12 other BMR and GSQ geologists, inspected the geology and mineral deposits of the Georgetown, Mount Isa, Arunta and Pine Creek regions during June.

INSPECTION OF MINERAL DEPOSITS

Derrick and Wilson accompanied D. Sangster of the Geological Survey of Canada in inspections of the Mount Isa, Hilton, Lady Loretta and Dugald River deposits.

MARY KATHLEEN

Further samples of skarn and conglomerate were taken from outside the open cut, in company with John Ferguson and B. Cruikshank. Garnet veins up to 6 cm wide were located in the marginal phase of the Burstall Granite. Results to date of the uranium-skarn solid solution equilibria studies are presented in the Petrology Laboratory report.

OVERHANG JASPILITE

Further field work on the Overhang Jaspilite has located recrystallised limestone with possible gypsum pseudomorphs - evidence of evaporative deposition. Three types of stromatolitic bioherm are present, and some examples are vertically striated. The lower part of the formation consists of about three cycles of shale, calcareous shale, limestone, and iron-rich chert. Mud-cracks in ferruginous mudstones are also present.

OFFICE ACTIVITIES

Maps

Final First Edition colour maps of Mary Kathleen and Marraba were issued, after many problems in the colour printing were overcome. Mount Isa First Edition is with the printers, and Kennedy Gap and Prospector are being edited for First Edition (colour). Cloncurry has been reinterpreted and is being prepared for First Edition also. Quamby Preliminary Edition was printed, and Alsace compilation sheets are being prepared.

Reports, publications.

Records on the Prospector (1977/4) and Mount Isa (1975/175) Sheet areas were issued. A record (1975/127) by B.A. Duff was issued, describing the geochemistry of black shale from DDH Cloncurry 5, Mary Kathleen Sheet area. Bulletin 193, describing the geology of Mary Kathleen 1:100 000 Sheet area, will be issued early in 1978.

Stratigraphic nomenclature articles parts VI and VII (Mary Kathleen and Mount Albert Groups) by Derrick, Wilson and Hill were published in the Queensland Government Mining Journal, and a paper by Derrick describing metasomatism and uranium mineralisation at Mary Kathleen appeared in the BMR Journal. A paper by Wilson comparing Mount Isa acid volcanics with Andean-type volcanics has been accepted by Precambrian Research. Wilson also summarised mineral exploration in the Mount Isa 1:250 000 Sheet area, in the Queensland Government Mining Journal.

Lectures, conferences

Derrick presented a lecture to the BMR symposium and AIMM North-West Queensland Branch on "Proterozoic Patterns of sedimentation north of Mount Isa". Hill spoke at BMR on the geology of the Overhang Jaspilite, and attended the Geological Society of Australia 2nd Convention in Melbourne.

Miscellaneous

Throughout the year project staff discussed aspects of the geology with visiting company geologists, held various meetings of the Mount Isa Discussion Group, and provided technical advice to BMR management, and edited and reviewed reports and manuscripts for publication.

DUCHESS PROJECT

STAFF: D.H. Blake (Project Leader, from July), R.J. Bultitude (Party Leader), C.M. Mock*, W.J. Perry (part time), T.A. Noon (GSQ), P.J.T. Donchak (GSQ, from July) G. Young (draftswoman, from August).

* (nee Gardner)

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, to review the stratigraphy, structure, and geological history, and to reassess the mineral potential of the area. The Precambrian rocks belong to the Cloncurry Complex (Carter, Brooks, & Walker, 1961), and are hosts to economic copper, silver, and cobalt mineralisation.

INTRODUCTION

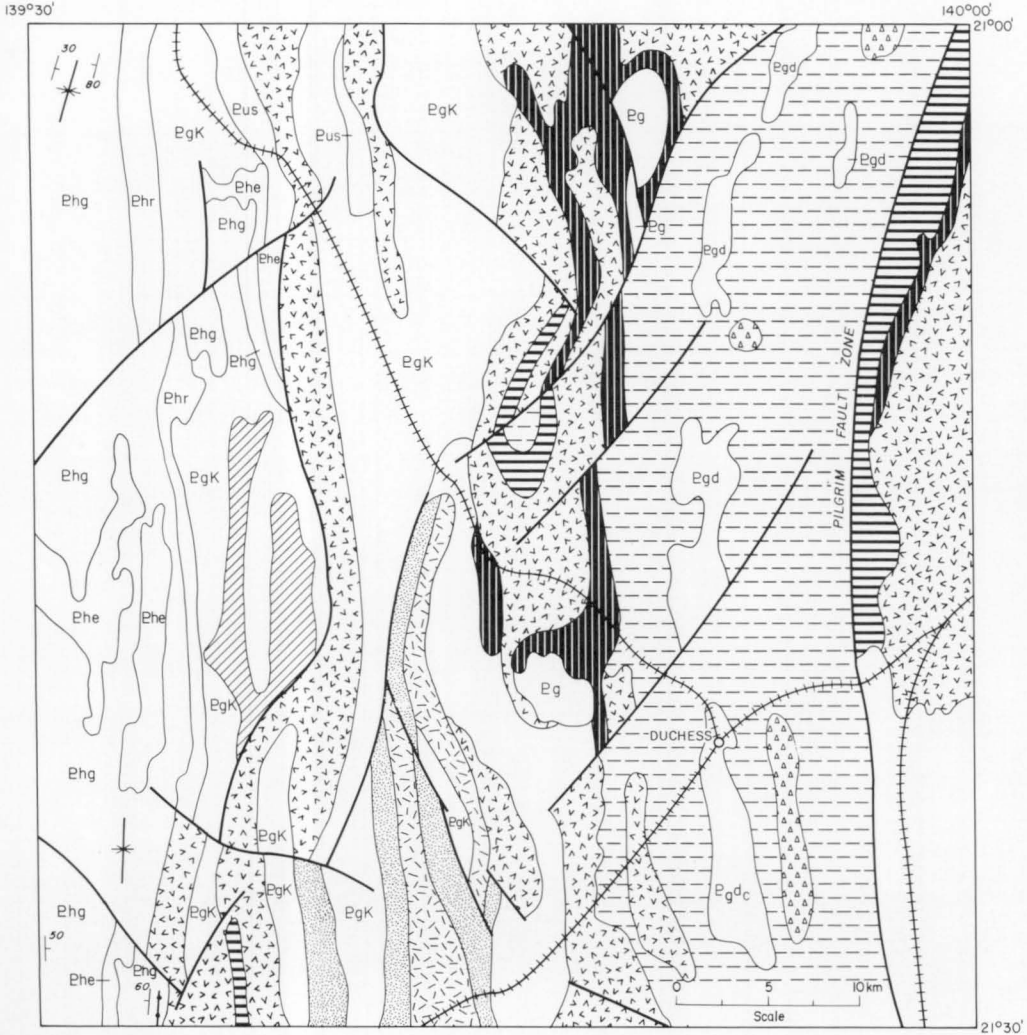
Office work during the year consisted of map compilation, airphoto interpretation, petrographic studies, and preliminary report writing by Bultitude, Mock and Noon for the Duchess, Oban and Malbon 1:100 000 Sheet areas respectively. In addition, the Dajarra 1:100 000 Sheet area was photo-interpreted by Perry. Field work was carried out from July to October. During this period Bultitude, Blake and Donchak completed the geological mapping of the Duchess and Dajarra 1:100 000 Sheet areas, and Noon made final field checks in the Malbon 1:100 000 Sheet area. Field work in the Oban Sheet area was completed in 1976. The remaining 1:100 000 Sheet areas are scheduled to be mapped in 1978.

During June, Blake & Bultitude participated in an inspection of the Georgetown, Mount Isa, Arunta and Pine Creek/Alligator Rivers regions, in company with other BMR geologists.

DUCHESS AND DAJARRA 1:100 000 SHEET AREAS (Figs. M10 & 11)

by D.H. Blake, R.J. Bultitude, and P.J.T. Donchak

The oldest rocks exposed in the Duchess and Dajarra 1:100 000 Sheet areas are metavolcanics and metasediments which in this report are combined as undivided 'Tewinga Group'. They include units previously mapped as Leichhardt Metamorphics, Magna Lynn Metabasalt, Argylla Formation, and rocks of the Malbon and Mary Kathleen Groups (Marraba Volcanics, Mitakoodi Quartzite, and Ballara Quartzite), and also gneissic rocks that were regarded as part of the Kalkadoon Granite and Wonga Granite. These units are now known to interfinger with one another in the northeastern part of the Duchess Sheet area, and here and to the south their typical constituent rock types have been found at various strati-



Makbat Sandstone — PEum — *Arenite, siltstone, shale, conglomerate*

Unnamed granite — PEg — *Massive to foliated granite*

Duchess Granite* — PEgd — *Pink medium to fine granite*

PEgdc — *Complex of granite, dolerite and dioritic hybrids*

Intrusive breccia — *Dolerite and intrusive xenolithic pink porphyry*

Surprise Creek Beds? — PEus — *Arenite, siltstone, shale*

Stanbroke Beds* — PEub — *Arenite, siltstone, limestone*

Standish Beds* — *Felsitic acid volcanics*; *Metabasalt*

Composite dyke: acid porphyry and dolerite

Hoslingden Group

Eastern Creek Volcanics — PEhe — *Metabasalt, arenite*

Mt Guide Quartzite — PEhg — *Quartzose arenite, basal conglomerate*

Rifle Creek Beds* — PEhr — *Acid to basic volcanics, arenite, greywacke, conglomerate*

Kalkadoon Granite — PEgK — *Porphyritic to even-grained granite and granodiorite*

Corella Formation — *Calc-silicate granofels, meta arenite, mica schist, para-amphibolite, metabasalt*

Undivided "Tewinga Group" — *Migmatite*; *Gneissic acid volcanics, quartz-feldspar porphy*; *Metabasalt*; *Meta arenite*

* *Name not yet approved*

Geological boundary

Major fault

Syncline

50 *Strike and dip of beds*

FIG.M10 General geology, Duchess
1:100 000 Sheet area

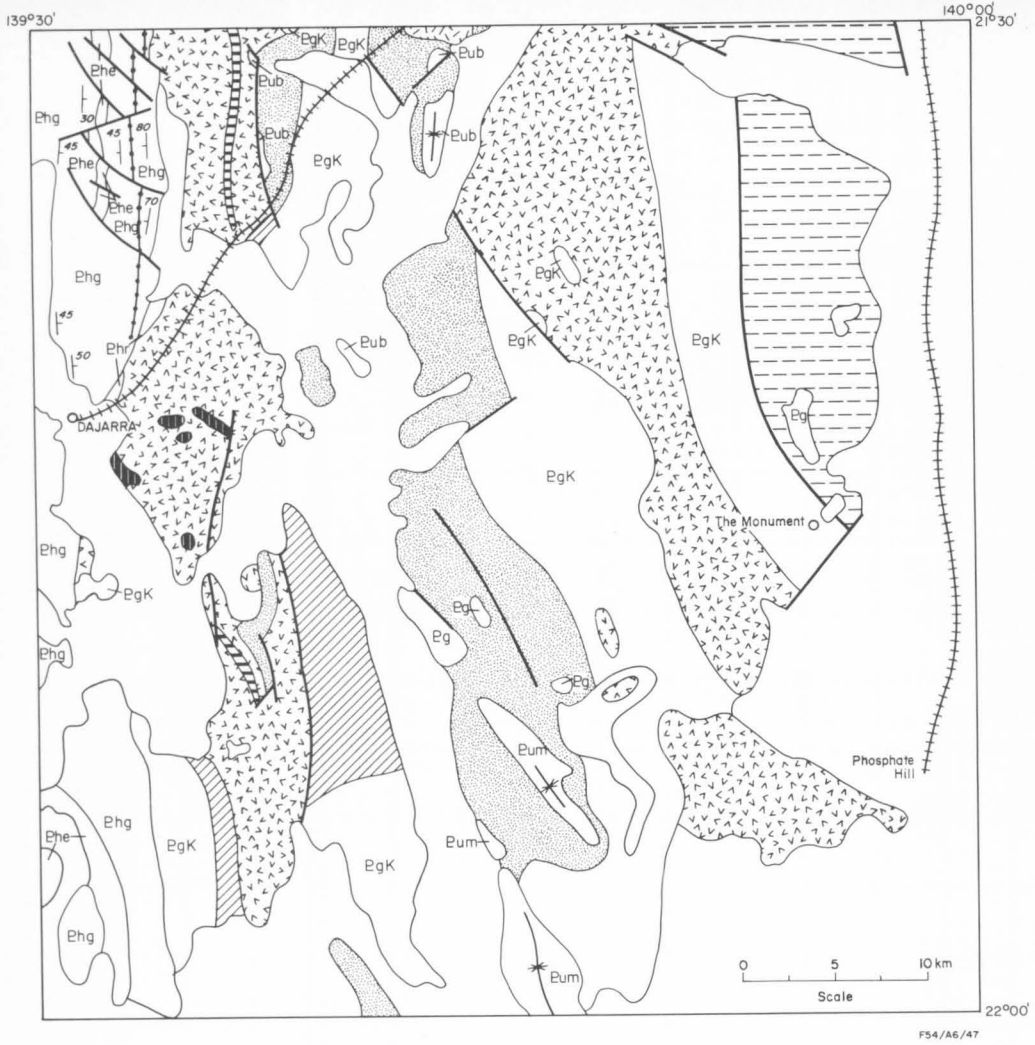


FIG.M11 General geology, Dajarra
1:100 000 Sheet area

graphic levels, rather than in a particular stratigraphic sequence that could be considered characteristic for the whole area.

The undivided Tewinga Group consists of fine to coarse-grained acid to basic gneisses and schists, quartzite, metabasalt, metarhyolite, and various foliated granitic to migmatitic rocks which represent partly granitised acid and intermediate volcanics and quartzofeldspathic sediments. Most of the gneisses were originally acid volcanics, probably tuffs: these include spectacular augen gneisses, some of which contain euhedral feldspar megacrysts 2 cm or more across in addition to smaller lensoid feldspar augen. Most of the schists are of more basic composition. Quartzite includes completely recrystallised arenites and perhaps rhyolites, and also little-altered quartz arenites in which sedimentary structures such as cross-bedding are well preserved. Metabasalt and metarhyolite, although completely recrystallised, commonly show some original volcanic features, such as amygdales and flow-banding, and are not as strongly foliated as the gneisses. The granitic and migmatitic rocks are cut by numerous fine-grained to pegmatitic leucocratic veins.

The rocks mapped as undivided 'Tewinga Group' are overlain concordantly, by and in places interfinger with, the Corella Formation. They are intruded by Kalkadoon Granite and innumerable basic dykes, and are overlain unconformably by Rifle Creek Beds and Mount Guide Quartzite of the Haslingden Group, by volcanics of the Standish beds (see below), and by arenites of the Stradbroke beds (see below).

The Corella Formation is made up of a wide variety of rocks: laminated to thickly bedded calc-silicates, calcareous granofels and recrystallised impure limestone; massive to well bedded meta-arenite (including quartzite) and metasiltstone; mica schist; banded chert; metabasalt; and thin slivers of acid porphyry that may represent extrusive acid volcanics. A thin belt of banded and partly hematitic chert, quartz arenite, and minor calc-silcates is present along the eastern margin of the Corella Formation outcrop. This belt may be equivalent to the Overhang Jaspilite north and east of the Duchess Sheet area. Gneissic acid tuff, consisting of interlayered coarsely 'porphyritic' and finer-grained non-porphyritic bands, occurs within the formatic south of Duchess. The Corella Formation is generally isoclinally folded about north-trending axes, and mainly has steep to near-vertical dips. Near Duchess the fold axes plunge north at about 15^{o}.

The field evidence in Duchess, Dajarra and Malbon 1:100 000 Sheet areas indicates that the Corella Formation belongs to the same 'package' of rocks as the undivided 'Tewinga Group', which it interfingers with and concordantly overlies. Hence it is inferred to be older than the Haslingden Group of the Western Succession, and to be older than the Kalkadoon Granite, in contradiction to the generally accepted view that the Corella Formation is much the youngest of these three units. Unfortunately, possible intrusive contacts with Kalkadoon Granite in the Dajarra Sheet area are obscured by faulting. Intrusive contacts between the Corella Formation and the younger Duchess granite and associated acid porphyry are well exposed near Duchess. The formation is intruded by basic dykes and sills, and also by bodies of intrusive breccia.

The Kalkadoon Granite consists mainly of medium to coarse, non-foliated to locally gneissic biotite granite and granodiorite which commonly contain abundant large phenocrysts of white to pink feldspar. Other rock types present are medium to fine diorite, biotite microgranite, leucogranite, aplite, and pegmatite. The unit intrudes and locally forms migmatites with gneissic metavolcanics and metasediments of the undivided 'Tewinga Group'. It is overlain unconformably by the Rifle Creek beds, Mount Guide Quartzite, Standish beds, Stanbroke beds, and probably Makbat Sandstone, and it is cut by numerous basic and some acid dykes. Most of the basic dykes have at least schistose margins, and are now amphibolite, actinolite schist, or chlorite schist. Acid dykes containing euhedral feldspar and quartz phenocrysts cut the Kalkadoon Granite in the north and also east of Dajarra; these dykes may be related to the acid volcanics of the Standish beds.

The undivided 'Tewinga Group' and Corella Formation have been regionally metamorphosed to at least amphibolite facies. This metamorphism probably took place during or shortly before the emplacement of the Kalkadoon Granite.

A major unconformity, well exposed in the western part of the area, indicates that a considerable time break separates the Kalkadoon Granite and older rocks of the basement from the overlying Haslingden Group. The rocks of this group have been regionally metamorphosed, but probably only to upper greenschist facies.

The basal unit of the Haslingden Group, the Rifle Creek beds, is at least 1000 m thick in the northwest but is absent south of Dajarra. It is made up of generally schistose basic to acid volcanics interlayered with quartzose to tuffaceous arenite, siltstone, and conglomerate. The acid volcanics are somewhat recrystallised, and individual phenocrysts are no longer well defined; however the recrystallisation is not as marked as in the acid volcanics of the undivided 'Tewinga Group'. The Rifle Creek beds are overlain conformably by the Mount Guide Quartzite, which in the southwest lies directly on basement rocks. At its base, the Mount Guide Quartzite commonly has a conglomerate similar to that within the Rifle Creek beds. Otherwise it consists of a ridge-forming sequence of extensively silicified, cross-bedded, feldspathic and quartz arenites which are commonly sericitic, especially in the lower part of the formation. The beds have been folded about north-trending axes and show a steep axial plane schistosity. They are intruded by numerous basic dykes and, in the central part of their outcrop, by a composite dyke. This dyke has narrow margins of dolerite and a relatively wide central zone formed of pink to dark grey microgranite containing large feldspar and smaller quartz phenocrysts.

The Mount Guide Quartzite is overlain, apparently conformably, by the youngest formation of the Haslingden Group recognised in the area. This formation, the Eastern Creek Volcanics, is a sequence of basaltic lavas, which are commonly schistose or strongly foliated, and interlayered lenses of quartzose and feldspathic arenite, some of which are conglomeratic. The lavas are amygdaloidal and have brecciated and generally epidotised margins, and they contain sparse copper mineralisation. Basaltic lavas exposed in the southwest are tentatively mapped as Eastern Creek Volcanics, but may underlie, rather than overlie, the Mount Guide Quartzite.

The remaining Precambrian units in the area appear to be younger than the upper greenschist regional metamorphism that affected the Haslingden Group and probably caused some retrogression of the high-grade older rocks.

A tightly folded and faulted but essentially non-schistose sequence of shale, siltstone, and feldspathic and quartz arenite in the northwest, unconformably overlying Kalkadoon Granite and Eastern Creek Volcanics, is tentatively assigned to the Surprise Creek Beds.

The Standish beds and Stanbroke beds are confined to the Dajarra and southwest part of the Duchess 1:100 000 Sheet areas. The Standish beds consist predominantly of acid volcanics which, unlike those of older formations, are generally felsitic and contain euhedral phenocrysts of quartz and feldspar. These volcanics are schistose only in the vicinity of faults. The unit also includes some basaltic lavas, schistose basic tuffs, and some quartz arenite lenses. The Standish beds overlie Kalkadoon Granite and older rocks unconformably, are overlain abruptly and perhaps unconformably by the Stanbroke beds, are presumed to be overlain unconformably by Makbat Sandstone, and are intruded by unnamed granite and basic dykes. They are not seen in contact with rocks of the Haslingden Group. The Stanbroke beds consist of friable to silicified quartzose and feldspathic arenites, siltstone, calcarenite, limestone, and, locally, a basal conglomerate. These rocks are exposed in the keels of partly fault-bounded synclines, where they have gentle to near-vertical dips.

Three main bodies of intrusive breccia, one previously mapped as Mount Philp Agglomerate, have been identified, all evidently emplaced within the Corella Formation after the main regional metamorphic events had taken place. The bodies contain disoriented angular blocks of foliated and regionally metamorphosed Corella Formation rocks ranging from less than 1 cm to several metres in length. These are enclosed in a sparse to abundant, medium to fine pink feldspathic matrix in which small euhedral amphibole phenocrysts are evenly distributed. Both bodies are cut by dyke-like masses of dolerite, some at least of which have highly irregular bulbous shapes, indicating that they may have been intruded before the breccia had solidified. The dolerite intrusions and breccia matrix have igneous textures and are not foliated.

The Duchess granite, like the intrusive breccias,intrudes the Corella Formation and is closely associated with relatively young dolerite intrusions. The main rock type is a pink, fine to medium-grained and locally porphyritic granite containing small amounts of biotite. Some aplite and associated pink feldspar porphyry are also present. The granite is generally foliated, and in places this foliation is tightly crenulated. Near Duchess the granite includes a net-veined complex, in which granite, contemporaneous or slightly younger dolerite, and various intermediate hybrids are intimately mixed. Within this complex the dolerite forms rounded to angular masses enclosed in and back veined by granitic rocks. Intricately crenulate contacts between dolerite and granite indicate that the basic magma intruded into acid magma rather than into solid rock.

Relatively young unnamed granite, mainly medium to coarse-grained leucocratic biotite granite, is exposed in the Dajarra Sheet area, where it intrudes acid volcanics of the Standish beds. It is itself intruded by basic dykes.

The youngest Precambrian unit in the area, the Makbat Sandstone, is exposed in two synclines in the southwest. It consists mainly of quartzose arenite and siltstone, and has generally gentle dips. The Makbat Sandstone overlies acid volcanics of the Standish beds and probably Kalkadoon Granite, and is cut by a single dolerite dyke.

The main centres of copper mineralisation in the area occur close to or within the Corella Formation, and all, with the possible exception of Mount Hope, north of Duchess, appear to be associated with basic or granitic intrusions. This includes the copper mines at Duchess, although most of these mines, including the main producer, the Duchess mine, lie within the net-veined complex of the Duchess granite.

OBAN 1:100 000 SHEET AREA (Figs. M12 and M13) by C.M. Mock

This year was spent in bringing the 1:100 000 scale geological map of the Oban Sheet area to Preliminary Edition stage, writing the first draft of a report on the geology of the Sheet area, and commencing a petrological and geochemical study of the Sybella Granite.

The Precambrian rocks exposed in the area comprise, from oldest to youngest, the Mount Guide Quartzite, Eastern Creek Volcanics, Myally Beds, Carters Bore Rhyolite, Sybella Granite, and the Mount Isa Group and Gunpowder Creek Formation. Petrographic work on the greywackes in the lower part of the Mount Guide Quartzite supports the conclusion of Derrick and others that these rocks consist of detritus derived from rapid erosion of a rising Kalkadoon-Leichhardt basement welt to the east and deposited in an unstable high-energy depositional basin. The greywackes are pebbly, and conglomeratic lenses are common. The pebbles include quartzite, sandstone, granite, aplite, basalt, and microcline, and are enclosed in a matrix of subangular quartz, microcline, biotite, muscovite, sphene, epidote, opaque oxides, zircon and apatite grains.

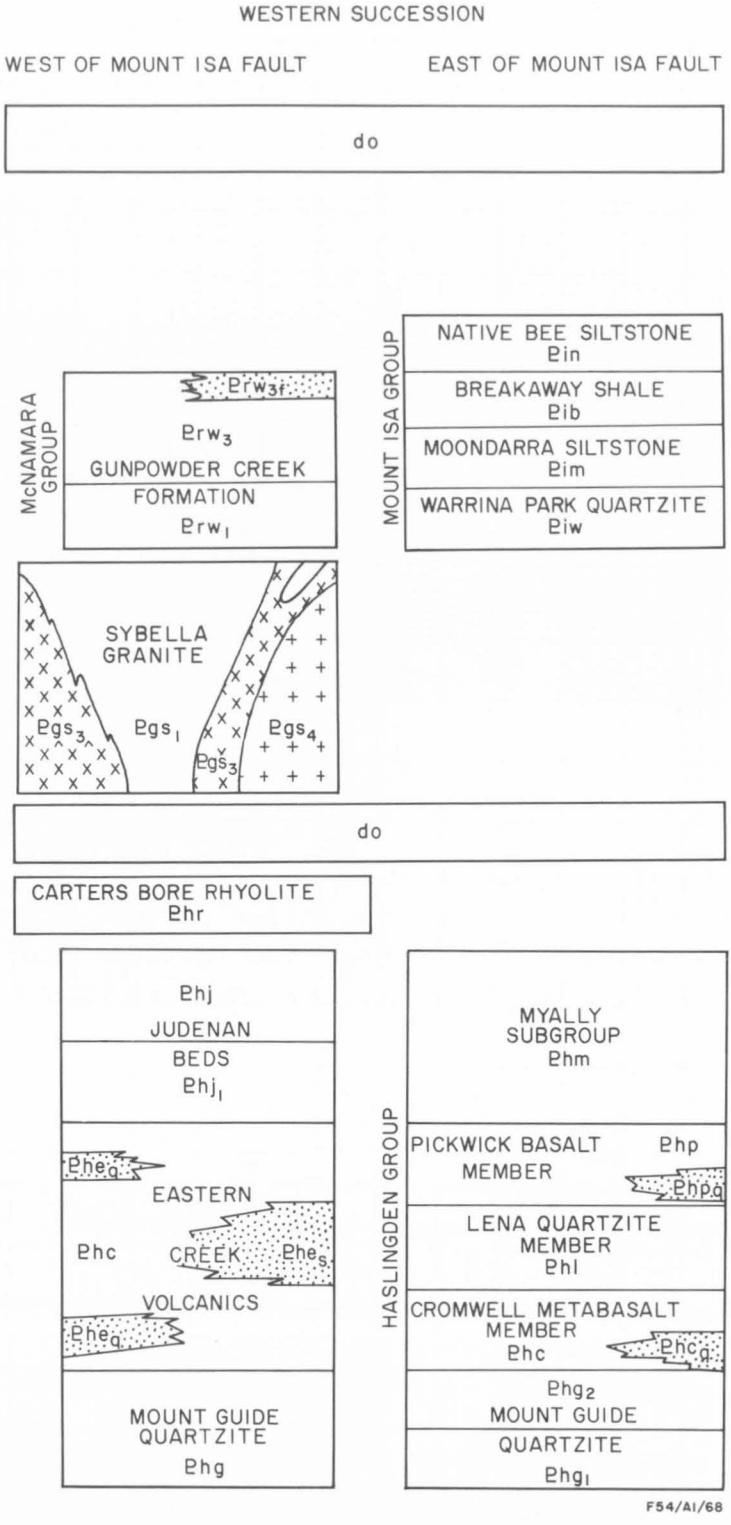


FIG.M12 Stratigraphy of Oban 1:100 000 Sheet area

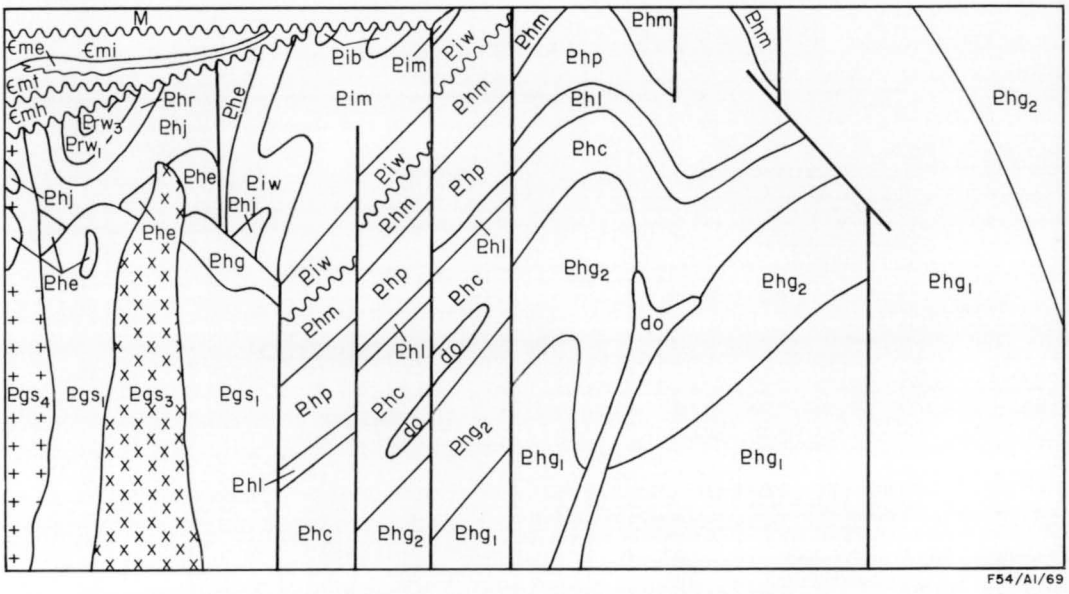


FIG.M13 Diagrammatic relationship of rock units

The Sybella Granite intrudes the Eastern Creek Volcanics and Myally Beds. It is mainly a medium to coarse, porphyritic, massive to foliated granite, but also includes small stocks and dykes of microgranite, aplite, and pegmatite. The foliation is defined by alignment of alkali feldspar augen and by 'braided' bands of groundmass minerals between the augen. Thin-section studies indicate that the granite was subjected to metamorphism as high as amphibolite facies. Contact affects between the granite and basic rocks of the Eastern Creek Volcanics are minimal except around a lensoid inlier of granite in the central part of the sheet area. Contact affects here decrease gradually eastwards and sharply westwards. The immediate contact zone is marked by numerous dark microgranite dykes, and there are many small stocks and dykes of leucogranite and white pegmatite within the general aureole. Within a metre or so of the granite the country rock is massive amphibolite cut by migmatitic-style granitic veins. Brown to black mica schist, hornblende schist, and cordierite schist predominate farther away from the granite. Gneissic rocks, in which granitic bands alternate with micaceous bands, form lenticular masses within the schists.

MALBON 1:100 000 SHEET AREA by T.A. Noon

The geological field research on the Malbon Sheet area was completed during the year, and a preliminary report on the geology of the area is nearing completion.

Some problems with the previous stratigraphic nomenclature have arisen. The current mapping shows that the Staveley Formation passes laterally into the lithologically similar Corella Formation, and usage of the term Staveley Formation has therefore been discontinued. Similarly, the Marimo Slate and Answer Slate should probably be merged as a single formation: they are similar in lithology, and both appear to be conformable on Overhang Jaspilite. Marimo Slate is the preferred name, as it has precedence in the literature.

There is no evidence in the Malbon Sheet area to indicate a major break in sedimentation between the deposition of sandstone in the upper part of the Argylla Formation (Tewinga Group), through to the deposition of the Kuridala Formation at the top of the Mary Kathleen Group.

Carbonaceous and sulphide-bearing black slate within the Answer Slate/Marimo Slate and Kuridala Formation appear to be the only rocks in the Sheet area which could contain high-tonnage low-grade copper or lead-zinc-silver deposits. They are currently being investigated by Conzinc Rio Tinto Australian Exploration Pty Limited and Getty Oil Development Company Limited.

Work on the Silver Phantom mine, 11 km southwest of Kuridala, progressed during the year, and substantial returns were recorded. The ore comprises naumannite, cerargyrite, and possibly argentite in a siliceous gangue associated with barite. Numerous nuggets of native silver have been recovered from alluvial flats southeast of the mine.

LAWN HILL PROJECT

by

I.P. Sweet and A. Mond

STAFF: I.P. Sweet (Project leader), A. Mond; L.J. Hutton (GSQ).

AIMS: The aims of the project are to carry out field research on the Precambrian rocks in the Lawn Hill and Carrara areas in order to elucidate their stratigraphy, structure, and geologic history, with the ultimate aim of reassessing their mineral potential.

INTRODUCTION

The Lawn Hill area forms the northwestern margin of a belt of Carpentarian rocks which extend from the Duchess and Mount Isa areas in the south. To the west of Lawn Hill the Carrara Range, and to the north of Hedleys Creek (Westmoreland) areas both contain Carpentarian sequences separated from the main belt by younger sequences. During 1977 fieldwork was concentrated on completing investigations in the Lawn Hill, Riversleigh, and Carrara Range areas. Hedleys Creek area had been mapped previously. We should now be able to refine correlations between the Lawn Hill, Carrara, and Hedleys Creek sequences and to thereby define the northwestern margin of the basin in which the Carpentarian rocks were deposited. Future fieldwork will be directed towards relating the units mapped at Lawn Hill to better-known sequences farther south and southeast.

CARPENTARIAN SEQUENCES

Lawn Hill and Riversleigh 1:100 000 Sheet areas

The oldest rocks in the area are amygdaloidal basalts interbedded with sandstone and overlain conformably by fine to medium-grained feldspathic sandstone and arkose; no acid volcanics were observed in the sequence. They have been tentatively assigned to the Fiery Creek Volcanics, a unit mapped in the Mount Oxide/Mammoth Mines area to the south. An alternative correlation of the basalt and arkose with the Eastern Creek Volcanics seems less likely. Intruding the basalt, but also truncated by the Ploughed Mountain Beds, is a leucocratic granite, the Weberra Granite, samples of which were collected by R. Page for age determination by the zircon method.

The Fiery Creek Volcanics in the western Mount Oxide 1:100 000 Sheet area consist of conglomerate overlain by altered basic volcanics, but farther north, on the margin of the Gregory Downs Sheet area, acid volcanics are present. Both outcrops are overlain unconformably by Ploughed Mountain Beds which contain, in their lower part, a thin, (2-5 m) laminated grey chert band, the 'Oxide Chert Member' of R.J. Cavaney (in Proterozoic Geology, abstracts of 1st Australian Geological Convention, Adelaide). The chert is absent from the sequence in the Lawn Hill Sheet area.

The sequence of carbonate and clastic rocks which form the bulk of the Ploughed Mountain Beds are well exposed in the Riversleigh and Gregory Downs 1:100 000 Sheet areas. In 1976 the sequence was divided into 13 units, Pm_1 to Pm_{13}, and of these units Pm_4 to Pm_8 are well exposed in the Riversleigh area. Pm_5 is a silty interval in the predominantly carbonate sequence Pm_4 to Pm_6. It also includes sandstone and stromatolitic chert, and is equivalent in part to the Esperanza Formation of Cavaney. Unit 6, which is predominantly dolomite at Lawn Hill, appears to become siltier eastwards.

The clastic sequence which forms roughly the upper half of the Ploughed Mountain Beds ($\mathbb{P}m_7$ to $\mathbb{P}m_{13}$) varies noticeably southeastwards from Lawn Hill. $\mathbb{P}m_7$, which is characterised by medium-grained orthoquartzites, is thickest in the central Riversleigh Sheet area in what must have been a locally rapidly-subsiding shelf. It thins eastwards but thickens towards the southeastern corner of Riversleigh. A thick sequence of $\mathbb{P}m_8$ shale, siltstone, and sandstone are also present. $\mathbb{P}m_9$, a coarse sandstone, lenses out in the southern part of the Lawn Hill Sheet area, and it is possible that $\mathbb{P}m_{10}$ to $\mathbb{P}m_{13}$, which have been traced southwards into the Riversleigh Sheet area, are thinner and finer-grained than in Lawn Hill Sheet area.

Re-examination of outcrops of $\mathbb{P}m_{13}$, a sequence of interbedded siltstone, sublithic arenite, and quartz greywacke revealed the presence of some graded bedding. This and other sedimentary features indicate that the unit was laid down at least partly by turbidity currents. It is possible that these rocks are a flysch facies occupying a small trough which was supplied with sediment from uplift of Mount Isa Group and older rocks to the east or southeast. Unfortunately the rocks are devoid of other current-produced sedimentary structures which might have aided provenance studies.

The youngest Carpentarian rocks in the area,the Lawn Hill Formation, extend only a few kilometres into the Riversleigh Sheet area from Lawn Hill, and are overlain unconformably by Cambrian limestone.

Carrara and Mitchiebo 1:100 000 Sheet areas

A sequence in the eastern Mount Drummond 1:250 000 Sheet area, previously mapped as Carrara Range Formation (sandstone and volcanics) and Bluff Range Beds (siltstone and dolomite) was further subdivided and studied in an attempt to relate it to the better-known sequences of Carpentarian age at Lawn Hill and Hedleys Creek.

Overlying metamorphic basement (Fig. M14) is a thick sequence of conglomeratic sandstone ($\mathbb{P}c_1$) succeeded by amygdaloidal basalt with interbeds of siltstone and sandstone ($\mathbb{P}c_2$). A prominent sandstone ($\mathbb{P}c_3$) which caps the basalt is overlain disconformably by acid volcanics ($\mathbb{P}c_4$). Valleys and

gorges eroded into the sandstone before extrusion of the acid lavas have been infilled and preserved by them. The acid lavas are overlain by massive conglomerate and sandstone (Ec_5) containing at least one interbed of acid volcanics (Ec_{5v}). The contact between Ec_4 and Ec_5 is probably unconformable, but the presence of volcanics in Ec_5 suggests that the time break may not be large. Above the sandstones, which form the top of the Carrara Range Formation, are poorly exposed, highly altered rocks mapped as Bluff Range Beds. They have been strongly affected by deep-weathering and lateritisation, and were probably dolomitic originally, but are now limonitic sandstone, siltstone and chert overlain by white leached claystone. The youngest part of the Carpentarian sequence, which is overlain by the Adelaidean or Carpentarian South Nicholson Group, consists of cross-bedded micaceous sandstone.

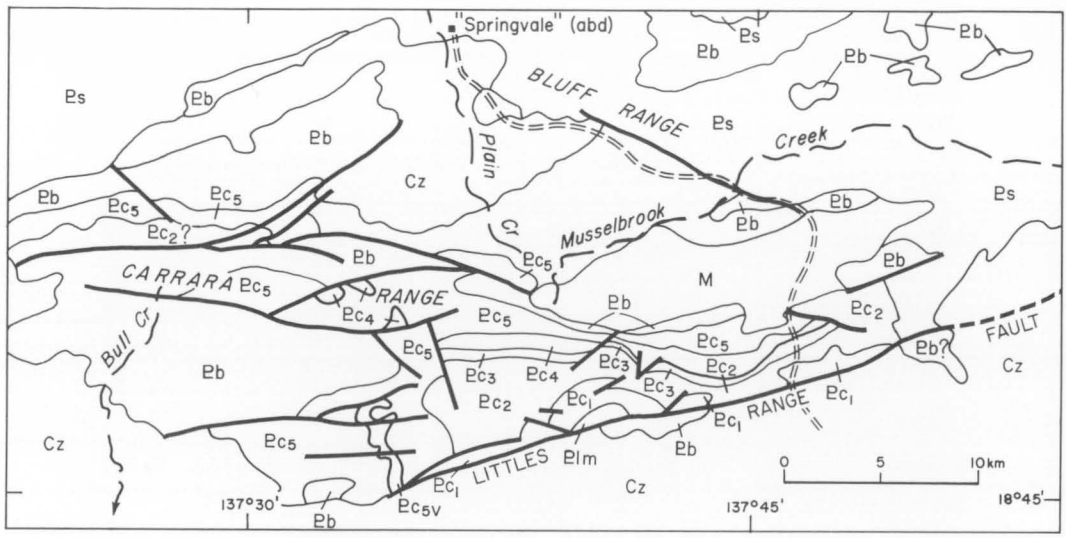
Correlations (Table M1)

Refinements of correlations between the sequences at Carrara, Hedleys Creek and Lawn Hill should permit a more accurate description of the geologic history of the region, and could lead to upgrading of the prospectivity of the Carrara area.

The lower part of the sequence in the Carrara area (Ec_1 to Ec_4) is very similar to the Wire Creek Sandstone and Peters Creek Volcanics in the Hedleys Creek area, and both of these sequences are correlated with the volcanics in the Lawn Hill area. The unconformity above the volcanics at Lawn Hill and Hedleys Creek may also be present at Carrara, between Ec_4 and Ec_5, although volcanism did recur after the hiatus.

The Bluff Range Beds are regarded as equivalent to the Fickling Group at Hedleys Creek and to the Ploughed Mountain Beds and Lawn Hill Formation at Lawn Hill. Carbonate and siltstone concretions which characterise the lower part of the Lawn Hill Formation have been found in the northernmost outcrops of the Bluff Range Beds, and micaceous sandstones are the youngest rocks in both sequences.

Thus, it seems likely that the Lawn Hill Platform, a relatively stable shelf west of the Mount Isa trough, extended well into the Northern Territory.



CAINOZOIC — Cz — *Sand, black soil, laterite*

MESOZOIC — M — *Sandstone, claystone*

PROTEROZOIC — South Nicholson Group — Ps — *Sandstone, siltstone, shale, conglomerate*

PROTEROZOIC – CARPENTARIAN — Bluff Range Beds — Pb — *Sandstone, siltstone, chert*

Carrara Range Formation:
- Pc_{5V} — *Acid volcanics*
- Pc_5 — *Sandstone, conglomerate*
- Pc_4 — *Acid volcanics*
- Pc_3 — *Sandstone*
- Pc_2 — *Basalt, sandstone*
- Pc_1 — *Conglomeratic sandstone*

Murphy Metamorphics — Plm — *Phyllite*

===== *Track*

E53/A12/6

FIG.M14 Portion of the Carrara and Mitchiebo 1:100 000 Sheets showing generalised geology of the Carpentarian rocks.

Mineralisation

Company activity has been concentrated on the lower part of the Ploughed Mountain Beds (Pm_4 to Pm_7), but no finds of base metals are known to us. Malachite staining occurs in sandstone in Pm_1 but its origin is not known.

Table M1: Correlation chart for Proterozoic rocks in the Lawn Hill, Carrara, and Hedleys Creek areas

CARRARA	HEDLEYS CREEK	LAWN HILL
South Nicholson Group	South Nicholson Group	South Nicholson Group
Bluff	Doomadgee Formation	Lawn Hill Formation Pm11 to Pm13
Range	Mount Les Siltstone	Pm8 to Pm10
Beds	Walford Dolomite	Pm4 to Pm7
Pc5	Fish River Formation	Pm1 to Pm3
	REGIONAL UNCONFORMITY	?Intrusion of Weberra Granite
Pc4 Pc3 Pc2	Peters Creek Volcanics	Basic volcanics- 'Fiery Creek Volcanics' (?)
Pc1	Wire Creek Sandstone	
	UNCONFORMITYY	
Murphy Metamorphics	Murphy Metamorphics	

No signs of mineralisation were seen in the Carrara area although it is possible that some of the limonitic outcrops interpreted as lateritised sediments may have developed on sulphides. Unexploited iron deposits shown on the Mount Drummond 1:250 000 Sheet are massive goethite, and may fit into this category.

STRUCTURE OF THE CARPENTARIAN ROCKS

The rocks in the Lawn Hill and Riversleigh areas are generally moderately folded into basin-and-dome structures which are cut by northwest and east-northeast-trending faults. Towards the eastern margin of Riversleigh the general trend of structures changes to northerly, and the sequence is steeply dipping. The sequence at Carrara is also moderately folded, and strongly faulted by a system of east-northeast and west-northwest-trending faults. The rocks have reacted to stress in a brittle fashion, and are cut by numerous small cross faults and strike faults of unknown displacement. Some of the major faults were reactivated later, during deformation of the South Nicholson Group.

ADELAIDEAN OR CARPENTARIAN SEQUENCE

South Nicholson Group

A folded and faulted sequence of sediments up to about 1000 m thick, the South Nicholson Group, occupies the northern parts of the Carrara and Mitchiebo 1:100 000 Sheet areas. The general geology has been compiled by Smith and Roberts (1963) on the Mount Drummond 1:250 000 Sheet. In this area the South Nicholson Group has been subdivided into two main units, the Constance Sandstone and the Mullera Formation.

The Constance Sandstone lies unconformably on the Bluff Range Beds and Carrara Range Formation and is overlain conformably by the Mullera Formation. The Constance Sandstone consists of medium to fine-grained, well-bedded to massive, in places cross-bedded and ripple-marked sandstones. In the Bluff Range area (Fig. M12) the sequence is about 400 m thick. The dominant rock type is white to light pink quartzose sandstone, commonly fine to medium-grained, rarely coarse-grained. Conglomerate and pebbly beds

occur at the base of the sequence and are best developed in the area north and west of Springvale Homestead. They are not very thick and in places form only lenses.

The Mullera Formation crops out in two areas. In the eastern Carrara Sheet area it is mostly obscured by Cretaceous and Cainozoic rocks, except in a small basin north of the Little's Range. The most common rock types are greyish-green and purple siltstone and shale, commonly micaceous, which are interbedded with fine to medium-grained quartzose sandstone, possibly equivalent to the Middle Creek Sandstone Member of the Musselbrook and Bowthorn Sheet areas.

West of Springvale Homestead (Carrara and Mitchiebo Sheet areas) an incomplete section of about 1000 m of Mullera Formation sediments is exposed. Greyish-green, yellowish-brown, and purple siltstone and shale are the most common rock types, and are overlain in a shallow syncline by quartzose and feldspathic sandstone, siltstone, shale, glauconitic and ferruginised sandstone, and ironstone. Equivalents of the Middle Creek Sandstone Member are missing. Cross-bedding is very common. Most of the northern limb of this syncline has been eliminated by the Mitchiebo Fault, and similar but smaller faults affect the southern limb.

GEORGETOWN PROJECT

by

J.H.C. Bain, D.E. Mackenzie & I.W. Withnall

STAFF: J.H.C. Bain[1], (Project Leader) B.S. Oversby[1], D.E. Mackenzie[1], I.W. Withnall[1] (GSQ), E.M. Baker (GSQ), A.G. Rossiter[2], P.A. Scott[2*], J.A. Major[3]*, L.P. Black[4], P.L. Blyth[5*].

[1]geology, [2]geochemistry, [3]geophysics, [4]geochronology, [5]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 regional geochemical and geophysical patterns, to determine the distribution, physical and chemical nature, source, and controls of the mineral deposits; to reassess the mineral resources and potential of the region; and to stimulate and assist mineral exploration there.

INTRODUCTION

In the first stage of the project (Fig. M15), investigations were mostly confined to a north-south strip 50 km x 150 km in the central part of the Inlier (namely Georgetown, Forsayth, and Gilberton, and adjacent parts of Mount Surprise and Galloway 1:100 000 Sheet areas). Stage-one field work has now been completed, with regional geological, geochemical, and geophysical coverage, and semi-detailed geological, geochemical, and geophysical investigations of the Mount Turner copper-molybdenum prospect and the Jubilee Plunger gold prospect. Laboratory studies, data processing and interpretation, report writing, and map production resulting from stage-one field activities are continuing.

The second stage of the project (Fig. M15) - investigations into the Georgetown Inlier in the Forest Home and North Head Sheet areas and adjacent parts of Abingdon Downs, Esmeralda and Gilbert River Sheet areas as far west as the eastern edge of the Croydon Volcanics - commenced in 1976, and the geological field work is now virtually complete. Only some check work and stratigraphic drilling remain to be done. Office studies will continue throughout 1978.

Stage three would entail investigation of Croydon Volcanics, Esmeralda Granite and related mineral deposits, and the production of a map of the area at 1:250 000 scale.

FIELD ACTIVITIES

Field work by Baker, Mackenzie, and Withnall in the Forest Home, North Head,and adjacent parts of Abingdon Downs, Gilbert River, and Esmeralda 1:100 000 Sheet areas entailed reappraisal of the Proterozoic stratigraphy, and the consequent redefinition of several units and the delineation of others. Earlier investigations of the structure of the Proterozoic metasedimentary rocks were extended, and the distribution and interrelationships of Proterozoic granitic rocks, and the distribution and nature of late Palaeozoic acid volcanic and related rocks were studied. Baker also supervised diamond drilling of geochemical and geophysical anomalies at Mount Turner for the Geological Survey of Queensland.

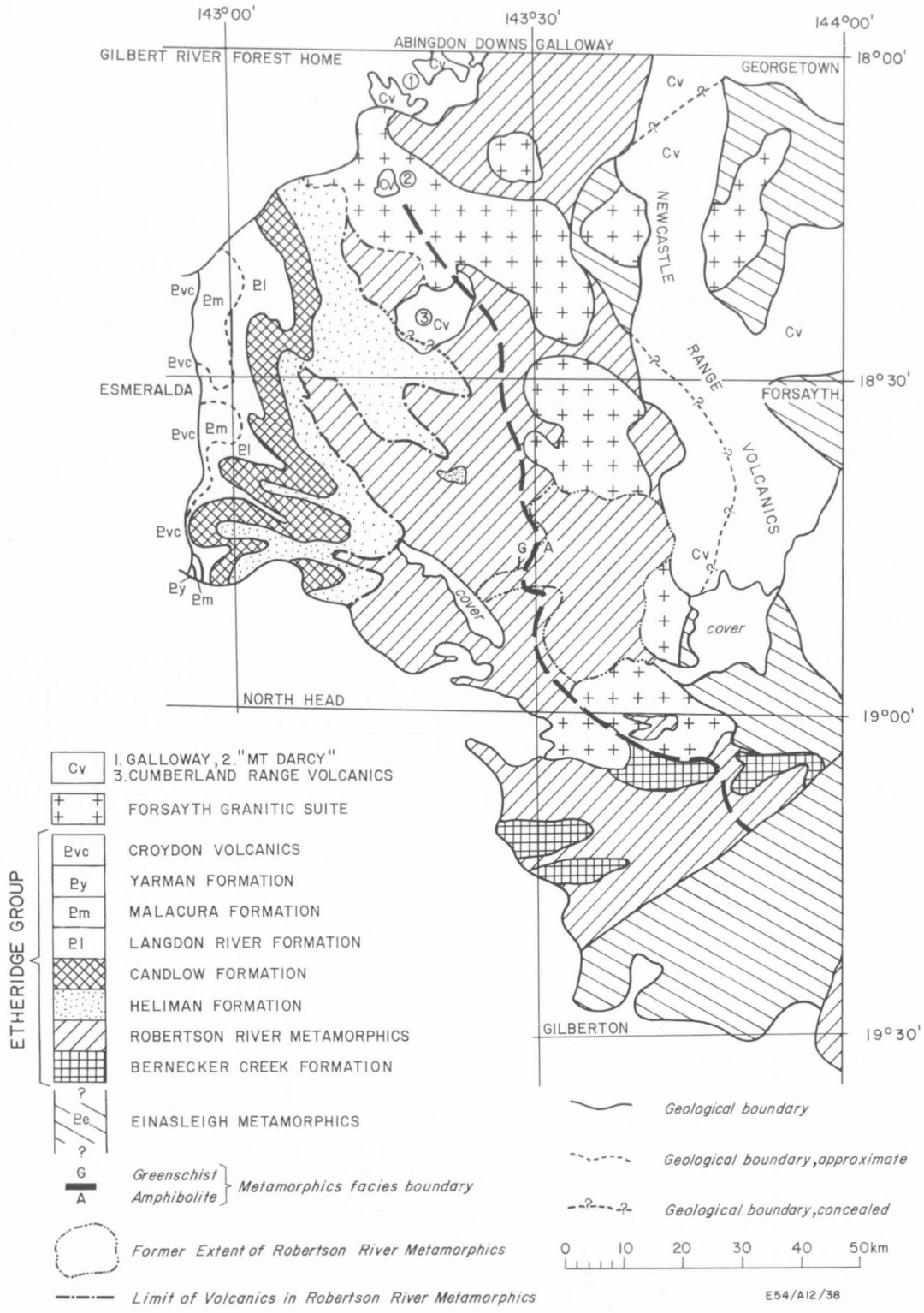


FIG.M15 Simplified geology of the Georgetown region, northeast Queensland

GEOLOGY

Etheridge Group

The Robertson River Metamorphics are the oldest rocks of the Etheridge Group that occur in the area investigated. They consist of schist, quartzite, and minor calc-silicate rocks, grading westwards and upwards into phyllitic and slaty siltstone, shale, and fine lithic and quartz sandstones; the rocks are commonly calcareous and are locally carbonaceous. Most of the phyllitic and slaty rocks were previously assigned to the "Etheridge Formation", but are now included in the Robertson River Metamorphics in compliance with the International Stratigraphic Code. The remainder of the "Etheridge Formation" has been subdivided, raised to Group status, and expanded to include the Robertson River Metamorphics as well as units which overlie the "Etheridge Formation" (Langdon River, Malacura, and Yarman Formations).

Sills of metadolerite and metagabbro (formerly "Cobbold Dolerite") are restricted to the Robertson River Metamorphics and are probably cogenetic with metamorphosed basic volcanic rocks (Dead Horse Metabasalt Member) in the southern part of the North Head 1:100 000 Sheet area.

The Robertson River Metamorphics are conformably overlain by the Heliman Formation (new name), a unit consisting of comparatively soft micaceous (sericitic) feldspatholithic siltstone, sandstone, and shale, all of which are commonly carbonaceous and/or pyritic, and more resistant black even-grained flinty siliceous siltstone which commonly contains pyrrhotite. The generally complex folding in the Heliman Formation is outlined by the prominently outcropping siliceous beds. The unit is at least 1000 m thick.

Conformably overlying the Heliman Formation is the Candlow Formation (new name), which consists essentially of the same rock types as the Heliman Formation, but in different proportions. Dominant rock types are recessively weathering dark grey carbonaceous shale and siltstone, which are phyllitic in part and commonly pyritic, feldspatholithic siltstone and fine sandstone, sericitic siltstone and fine sandstone, and probable ashstone. Black flinty siliceous siltstone is generally scarce, except in the lower half of the Candlow Formation, which contains an almost continuously outcropping siliceous member (as yet unnamed) lithologically similar to those in the Heliman Formation. The upper half of the formation contains the massive black highly carbonaceous and commonly pyritic Stockyard Creek Siltstone Member.

The Candlow Formation is overlain conformably by the Langdon River Formation, which consists of dark grey to purple-grey or maroon, commonly phyllitic shale, siltstone, and rare fine sandstone. The lowest part of the unit tends to be the most carbonaceous, and is finely banded; the middle parts are more homogeneous and ferruginous, and the upper parts are banded and pyritic, and contain some sandstone.

Overlying the Langdon River Formation is the Malacura Formation (new name), a unit consisting predominantly of fine, even-grained feldspatholithic sandstone, with coarser-grained sandstones, tuffaceous sandstones, and tuff near the base, and some intercalated carbonaceous siltstone and shale. This unit is in turn overlain by the Yarman Formation (new name) which is predominantly dark grey to maroon shale and fine siltstone, and cross-bedded fine-grained lithic-quartz sandstone.

Forsayth plutonic suite

Subdivision of the Proterozoic granitic rocks was further refined and extended into newly investigated areas. The predominant unit is the Forsayth Granite (a strongly porphyritic biotite granite), bodies of which become smaller and "higher-level" (contact aureole-type) westwards. This granite is intruded by an inhomogeneous muscovite-biotite granite (Delaney Granite), which is host of the Mount Turner deposit, and is in turn intruded by the Aurora Granite - coarser-grained leucocratic muscovite-biotite granite and pegmatite.

Forest Home Granodiorite; Esmeralda Granite; Croydon Volcanics

A number of small, rounded plutons of even-grained biotite granodiorite (Forest Home Granodiorite) which intrude the Heliman, Candlow, Langdon River and Malacura Formations have pronounced contact metamorphic aureoles. These plutons are distinct from the coarser-grained grey, graphite-bearing granitic rocks (Esmeralda Granite) which occur along the eastern boundary of the Croydon Volcanics. The Esmeralda Granite is genetically related to the Croydon Volcanics, a thick sequence of dacite to rhyolitic ignimbrites and lavas which unconformably overlies the Etheridge Group.

Carboniferous volcanic and related intrusive rocks

The Galloway Volcanics in Forest Home and Abingdon Downs Sheet areas, the Cumberland Range Volcanics, and volcanic rocks in the Mount Darcy and Mount Tabletop areas are equivalents of the Newcastle Range Volcanics to the east. They consist of rhyolitic to dacitic ignimbrites and minor lavas with lesser amounts of andesite and basalt, and rest on patchily developed or preserved fine to very coarse-grained epiclastic sediments. Basic lavas are common in the Galloway Volcanics and in the Mount Darcy area, but rare in the Cumberland Range and absent at Mount Tabletop. Sediments are most abundant on the eastern sides of the Galloway (Maureen U-F-Mo prospect) and Cumberland Range areas, and at Mount Tabletop. In the Cumberland Range, extensive intense brecciation of the underlying Robertson River Metamorphics has resulted in large inliers and rafts of breccia being caught up in the volcanics, and abundant small angular metamorphic fragments being incorporated into the lower ignimbrite sheets. Spatially and genetically associated with the extrusive rocks are large masses of prophyritic microgranite (Prestwood Microgranite) and numerous small stocks, plugs and dykes of dacitic and rhyolitic porphyries.

Structure and metamorphism

Three major folding events affected the Etheridge Group in the area investigated. The first, D_1, was the most widespread and produced tight folds about easterly-trending axes, with major folds of 5 to 10 km wavelength and local parasitic folds of wavelength from outcrop scale to one or two kilometres. Associated with D_1 folds is an axial plane cleavage which grades northeastwards into a schistosity where D_1 metamorphic grade increases from lower greenschist to amphibolite facies. Metamorphic grade also increases markedly toward the main mass of the Forsayth plutonic suite, suggesting that the granites may have been formed during D_1.

Superimposed on D_1 folds are smaller, mainly north-south folds (D_2) with wavelengths generally less than 2 km. Intensity of deformation and accompanying metamorphism decreases from a strongly overprinting schistosity and amphibolite facies in the east to crenulation cleavage or broad warps in earlier folds and greenschist grade to indiscernible metamorphism in the west and southwest.

The third phase of deformation (D_3) produced folding about east-west axes and was most intense in the east-central part of North Head Sheet area where tight overturned folds with northerly dipping axial planes were delineated. To the north and west, where D_3 folds are more open, D_3 was weaker and its main effect was the steepening of the limbs of D_1 folds and the production of interference patterns in the hinges of these folds. Little or no metamorphism was associated with D_3.

The effects farther west in the North Head and Forest Home Sheet areas of two later folding events detected by staff of the James Cook University in the east-central part of North Head and adjacent part of Forsayth Sheet areas are unknown, but are likely to be weak and not regionally significant.

Economic geology

Several deep (200 to 300 m) holes were drilled by the Geological Survey of Queensland to test geochemical (Cu and Mo) and geophysical (resistivity and chargeability) anomalies at Mount Turner.

Within the Etheridge Group the presence of tuffaceous sediments and small amounts of primary sulphides (mainly pyrite and pyrrhotite) disseminated through some horizons, and the scattered occurrence of gossanous horizons, veins, and dykes may indicate a geological environment potentially prospective for stratiform or stratabound base-metal sulphides.

Sedimentary rocks beneath and within the Carboniferous volcanic rocks are currently a target for uranium exploration.

Geochronology

Additional samples of the Forsayth plutonic suite were taken for Rb-Sr dating, together with further material from the Robertson River and Einasleigh Metamorphics for zircon dating.

OFFICE ACTIVITIES

Uranium mineralisation

The level of exploration activity in the region has increased markedly over the last twelve months, search for uranium deposits being the main objective. Consequently a paper which documented several uranium

occurrences in the region, discussed their relationships with late Palaeozoic magmatism and pointed to the considerable exploration possibilities throughout the Cairns-Townsville hinterland was prepared and published in the BMR Journal.

Regional stream sediment geochemistry

Much time was spent in the development of appropriate raw data processing and presentation techniques and media and in the interpretation of the data from the Forsayth Sheet area, as reported by Rossiter and Scott elsewhere in this Summary. These geochemical data indicate, for the first time, extensive areas with anomalously high levels of Sn, U, and As. The exploration significance of these areas would not have been apparent without the geochemical data. Furthermore, the data confirm the conclusion reached as a result of the geological mapping that there are no extensive surface exposures of porphyry-copper-type mineralisation within the Sheet area.

Geochronology

Dating of granite, metamorphics, and acid volcanics by L.P. Black, of the Geochronology Group, continued throughout the year, as described in the Petrological Laboratory report. An integrated program of isotopic dating and regional and detailed local structural analysis of the Precambrian metamorphic rocks has demonstrated the temporally discrete nature of several regional Proterozoic deformational events, and that apparently in multiply deformed polymetamorphic rocks the Rb-Sr system is set by the event that produced the last penetrative schistosity. It is clear therefore that meaningful dating of such rocks can only be achieved if samples are collected on the basis of both detailed local and regional structural analysis.

Maps and reports

Field compilation sheets and Preliminary Editions of Georgetown, Forsayth and Gilberton Sheet areas, and field sheets of parts of Galloway and Mount Surprise areas covering the Newcastle Range Volcanics have been issued.

Reports and papers have been issued or published dealing with (i) the geology, (ii) mines and mineral deposits of the Forsayth Sheet area, (iii) geochemical orientation studies of the central part of the Inlier, (iv) exploration in the Inlier from 1962 to 1976, (v) geological and geochemical investigations of the Jubilee Plunger gold deposit, (vi) soil geochemistry of the Big Reef/Two Micks area, (vii) uranium mineralisation associated with Late Palaeozoic magmatism, (viii) new and revised names for intrusive rock units in the Georgetown-Forsayth area, (ix) Early Carboniferous fossils from the Cumberland Range Volcanics, (x) reconnaissance geology of the Woolgar River area and southeastern parts of the Gilberton 1:250 000 Sheet area.

In addition, the following are in various stages of preparation:

1. geological field compilation sheets and observation point overlays at 1:25 000 scale for North Head and Forest Home Sheet areas;
2. five maps and accompanying record on the stream sediment geochemical survey of the Forsayth Sheet area;
3. geological data summaries, Georgetown and Gilberton Sheet areas;
4. a description of the mines and mineral deposits of the Georgetown Sheet area;
5. accounts of detailed geophysical investigations in the Georgetown area in 1975 and 1976;
6. an interpretation of the regional geophysical data in the Forsayth Sheet area.
7. map and accompanying report on investigations of the Mount Turner porphyry copper-molybdenum prospect.

MISCELLANEOUS

Additional activities included the monitoring of exploration activity, attendance at conferences and symposia, the preparation and presentation of lectures, the provision of technical advice and information to BMR management and to exploration company geologists, and the refereeing of reviewing of papers for publication. Bain, Oversby and Withnall participated in the group inspection of BMR metalliferous project areas in northern Australia during June. This entailed the preparation of notes and itinerary for, and guidance of, the excursion through the Georgetown area.

VOLCANOLOGY AND ORE GENESIS, PAPUA NEW GUINEA

by

R.W. Johnson, D.E. Mackenzie (part-time), and R.J. Bultitude (part-time)

INTRODUCTION

During this year geological and petrological studies of Papua New Guinea volcanoes concentrated particularly on the regional tectonic implications of Quaternary volcanism, on gathering trace-element geochemical results for volcanic rocks, and on writing accounts of volcanic activity in Papua New Guinea. Comprehensive reports were completed on (1) the 1953-57 eruption of Tuluman volcano, (2) the geology and petrology of the Highlands volcanoes, and (3) the eruptive history of Bagana volcano. Results of other studies were presented as papers for both BMR and outside publications, partly in conjunction with GSPNG and Australian National University (ANU) personnel; summaries of these papers are given below.

RHYOLITIC VOLCANIC ACTIVITY IN A MARGINAL BASIN: THE 1953-57 ERUPTION OF TULUMAN VOLCANO, PAPUA NEW GUINEA by R.W. Johnson

A compilation has been made of the volcanological observations made by M.A. Reynolds and J.G. Best (former BMR geologists) of the 1953-57 Tuluman eruption. These observations were previously reported in BMR Records issued in the 1950s. The compilation integrates the contents of these Records, and includes reviews of geological and petrological results from Tuluman and other volcanic islands in the St Andrew Strait area, as well as a discussion of the tectonic setting of the volcanoes. The following is a summary of the compilation which has been submitted to the GSPNG for consideration as a memoir. Reynolds, Best, and Johnson are the authors.

Rhyolitic volcanic activity off the southern tip of Lou Island in the St Andrew Strait area of northern Papua New Guinea, began in June 1953. At the end of the eruption in January 1957, two new islands - the Tuluman Islands - had been formed. Seven phases of volcanic activity and eight principal centres of eruption are recognised. The earlier phases were characterised by dominantly submarine activity, and they produced fields

of floating lava masses. The climax of the eruption was reached in the fifth phase, between February and June 1955, when five different vents were active. Activity then declined, and there followed a 7-month period of quiescence. In November 1956 the final phase took place, producing subaerial lava flows. Many of the volcaniclastic deposits of the Tuluman Islands were eroded away after the end of the eruption, and the lava flows of the final phase of activity now make up the greater part of the larger of the Tuluman Islands. The Tuluman rhyolites are chemically similar to those found on other islands in St Andrew Strait, and are thought to have originated by partial melting of the basaltic crust that overlies a conjectured mantle hot spot beneath the strait.

HOT-SPOT VOLCANISM IN ST ANDREW STRAIT, PAPUA NEW GUINEA: GEOCHEMISTRY OF A QUATERNARY BIMODAL ROCK SUITE by R.W. Johnson

A study has been completed of the trace-element geochemistry of rocks from islands in St Andrew Strait, including Tuluman volcano. X-ray fluorescence analytical results were obtained by I.E.M. Smith (Department of Geology, ANU) and mass spectrographic results for the rare earth elements were determined at the Research School of Earth Sciences (under the supervision of S.R. Taylor). A paper is ready for submission to the BMR Journal. The authors are Johnson, Smith, and Taylor, and the abstract of the paper is as follows:

Four distinct volcanic rock types provide a striking example of contrasting magma compositions above a possible mantle hot spot in St Andrew Strait. Hypersthene-normative basalts on Baluan Island are geochemically similar to those on oceanic islands and, together with voluminous alkali-rich rhyolites on Tuluman, Lou, and Pam Islands, constitute a strongly bimodal rock suite. The rhyolites are regarded as partial melts of basaltic crust isotopically similar to the basalts of Baluan. In contrast, quartz-tholeiite basalts in the Fedarb Islands are isotopically distinct from the Baluan basalts; they are associated with dacite, and may be the mafic parent from which the dacite was derived by crystal fractionation.

PAPUA NEW GUINEA HIGHLANDS VOLCANOES PROJECT, by D.E. Mackenzie

A major report (ca 300 pp) on the morphology, geology, petrology, and origin of the Late Cainozoic volcanoes of the Papua New Guinea Highlands was completed and copies were submitted to the University of Melbourne on July 1 as a Ph.D. thesis; a copy will also be lodged with the BMR library. The following is a brief summary of the principal conclusions.

Late Cainozoic volcanic rocks of island-arc character in the continental-margin Papua New Guinea Highlands cannot be directly related to currently popular genetic models involving contemporaneous subduction. Subduction beneath part of the Australian continental plate during the mid-Cretaceous produced limited volcanism and widespread chemical modification of the lower lithosphere. Rapid and pronounced changes in tectonic setting prevented extensive volcanism from the modified lithosphere until favourable conditions were produced after the continent collided with a Tertiary island arc to its northeast and relatively stable tectonic conditions were resumed.

ERUPTIVE HISTORY OF BAGANA VOLCANO, by R.J. Bultitude.

A detailed account of Bagana Volcano is to be publised in the Memoir series of the Geological Survey of Papua New Guinea. A summary of the account follows:

Mount Bagana is a highly active volcano in the centre of Bougainville Island, Papua New Guinea, but because of its isolated position, the eruptive history, especially before about 1950, is largely unknown and poorly documented. Since 1947 the volcano has been almost continuously active. Major eruptions, characterised by violent explosive activity occurred in 1950, 1952, and 1966, during which ash clouds, nuees ardentes, and lava flows were produced; fifteen nuees ardentes were observed in 14 consecutive days in March 1952. Slow extrusion of lava may continue for months, even years, and is not always accompanied by explosive activity. Lava was extruded more or less continuously from 1972 to early 1975, but no reports of any explosive activity were received at the Central Volcanological Observatory, Rabaul. Since 1875, the main activity from Bagana between eruptive episodes has been the almost continuous emission of dense white vapours from the summit area.

Unlike other active volcanoes in Papua New Guinea, Bagana appears to be built up mainly of thick, steep-sided blocky andesitic lava flows with rounded, steep-sided fronts up to about 150 m high; pyroclastic deposits are relatively minor. Since 1943 at least eighteen lava flows with fronts at the base of the cone or on the lower and intermediate slopes of the volcano have been extruded. It has not been possible to determine any cycle or periodicity in the pattern of eruptive events, possibly because of the general lack of comprehensive observations.

The lavas are highly porphyritic, especially in plagioclase. Clinopyroxene is ubiquitous and is the next most abundant phenocryst phase. Most of the lavas contain minor orthopyroxene as small, faintly pleochroic phenocrysts and granules, and sparse large phenocrysts of brown hornblende. The hornblende is generally surrounded by reaction rims of opaque oxide, clinopyroxene, and plagioclase. Some rocks contain rare small olivine phenocrysts, generally to the exclusion of orthopyroxene. The rocks are quartz-normative, predominantly low-silica andesites, and display only a very small range in element abundances.

CONTRIBUTION ON PNG VOLCANOES TO VOLCANOLOGY ENCYCLOPAEDIA by R.W. Johnson

This paper, entitled "Papua New Guinea", was written for the Encyclopedia of Volcanoes and Volcanology (editor J. Green) to be published in 1978 as one of a series of earth sciences encyclopaedias (general editor R.W. Fairbridge). The authors of the paper are R.J.S. Cooke (GSPNG) and Johnson. The paper aims to provide a comprehensive review of volcanology in Papua New Guinea by describing the regional geological setting, identifying the main volcanic provinces and the active, dormant, and extinct centres, and by providing geological descriptions of the volcanoes, summary accounts of eight important eruptions, and a history of volcanological investigations. The account is extensively illustrated with photographs, and there are several tabulations of volcanological information.

CONTINENT-ARC COLLISION AND REVERSAL OF ARC POLARITY: NEW INTERPRETATIONS FROM A CRITICAL AREA BY R.W. Johnson and A.L. Jaques

Jaques presented this paper at the symposium held in honour of Professor S.W. Carey at the University of Tasmania. The paper is to be published in the Symposium Proceedings; the following is the abstract.

Northern New Guinea has been regarded as a region where the polarity of an island arc was reversed following collision with the Australian continent in the Tertiary. However, the evidence for this reversal is not compelling. Because present-day volcanism off the north coast of mainland Papua New Guinea is associated with a steeply northward-dipping Benioff zone (almost vertical), and Late Cainozoic volcanoes in the central highlands to the south cannot be related to any present-day Benioff zone, a more acceptable interpretation is that, following collision, the northward-dipping slab beneath the arc became suspended nearly vertically. The active marginal basin lying to the north of the arc, which began to form above the inclined downgoing slab before the collision, is unlikely to be subducted southwards beneath the mainland, because the lithosphere beneath marginal basins appears to be neither thick nor cold enough for the initiation of subduction. Polarity reversal, therefore, may not be the inevitable consequence of continent/arc collisions. Instead, the downgoing slab may steepen, equilibrate with the surrounding mantle, and lose its identity. Continuing convergence may be taken up at other plate boundaries, and the accreted arc may never again become active.

DELAYED PARTIAL MELTING OF SUBDUCTION-MODIFIED MANTLE IN PAPUA NEW GUINEA

by R.W. Johnson and D.E. Mackenzie

This study is an updated version of a paper presented at the International Geological Congress in August 1976. The authors are Johnson, Mackenzie, and I.E.M. Smith, and the paper has been accepted for outside publication.

Late Cainozoic volcanoes in Papua New Guinea may be assigned to nine volcanic provinces, seven of which are related to arc-trench systems. Four of these seven are associated with present-day subduction of lithosphere at currently active convergent plate boundaries. In contrast, volcanism in the three other provinces does not appear to be related to Late Cainozoic subduction; in these, the rocks are characterised by high LILE contents and higher $^{87}Sr/^{86}Sr$ values than are rocks from the other provinces, and their chondrite-normalized REE patterns are more strongly fractionated (La/Yb 7).

The primary magmas of the three provinces are thought to have originated in mantle lithosphere which had been chemically modified in the Early Cainozoic, or Late Mesozoic, by slab-derived fluids rich in water and LILE. During the Late Cainozoic this chemically modified lithosphere may have become involved in new tectonic regimes that favoured anatexis of the hydrated peridotite, but which did not involve subduction.

CRITICISM OF GENERALISED MODELS FOR THE MAGMATIC EVOLUTION OF ARC-TRENCH SYSTEMS by R.W. Johnson

Following is the abstract of a paper written by R.J. Arculus (ANU) and Johnson, and submitted for outside publication.

Recent geological and petrological results from the Lesser Antilles island arc, Papua New Guinea, and other regions of arc-trench-type volcanism provide notable exceptions to the spatial, volumetric, and temporal relationships claimed for generalised arc models. For example, many alkaline and shoshonitic associations do not appear to be developed over the deepest parts of downgoing slabs, and there are now several well documented exceptions to the K_2O/SiO_2/depth-to-Benioff-zone relationship. Moreover, the temporal sequence of early tholeiitic → middle calcalkalic → late shoshonitic/alkalic is not well substantiated, although shoshonitic rocks do appear to be developed in regions with a long history of plate interactions. Exceptions to the generalised arc model are symptomatic of the need to look for the unique features of individual island arcs, rather than just similarities between different ones, so that the major factors controlling arc evolution may be determined.

ACQUISITION OF ANALYTICAL DATA by R.W. Johnson

A particular effort has been made throughout the year to obtain high-quality trace-element and isotope analytical data for a wide range of volcanic rock types from Papua New Guinea. About 120 whole-rock samples have now been analysed for rare-earth and other trace elements using the MS7 spark source mass spectrograph facility at the Research School of Earth Sciences (ANU), and B.W. Chappell (Department of Geology, ANU) has provided X-ray fluorescence results for 368 samples. Nine samples from the New

Britain island arc were sent to Professor G.J. Wasserburg and D.J. DePaolo of the California Institute of Technology, and a collaborative project is under way to report Sm-Nd isotope and $^{87}Sr/^{86}Sr$ systematics. All these analytical results provide a large data base for studies to be undertaken next year.

MISCELLANEOUS PROJECTS, PAPUA NEW GUINEA

STAFF: R.J. Ryburn, P.E. Pieters, G.P. Robinson, D.S. Hutchison, A.L. Jaques

NEW BRITAIN by R.J. Ryburn

A paper on the geology, mineral environment, and tectonic history of New Britain is being compiled. Of particular interest are the porphyry copper deposits of New Britain, and the possible closer proximity of New Britain to eastern Papua in the Early Tertiary.

THE SOUTH SEPIK BLUESCHISTS by R.J. Ryburn

A study of the metamorphism and tectonic history of blueschists and associated rocks from the south Sepik area of PNG is being completed. The study is being undertaken (in his own time) as a Ph.D. thesis (University of Auckland). Work done during the year includes evaluation of the physico-chemical conditions of metamorphism by application of experimental data and thermodynamics to the natural mineral assemblages, and the variation of conditions with time. A computer program was developed to deal with non-ideal mixing of fluid-phase components during metamorphism. Unmixing of H_2O and CO_2 is likely at the P-T conditions of lawsonite-glaucophane zone metamorphism. The study is currently being written up.

OTHER PROJECTS by P.E. Pieters

P.E. Pieters partly rewrote and expanded on the Kikori 1:250 000 Sheet Explanatory Notes for a more detailed report on the Kikori Sheet and immediately surrounding area. The report will be issued by the Geological Survey of PNG. The drafting of the Kikori 1:250 000 geological map was completed. He also wrote a first draft of a paper on the Owen Stanley Metamorphics for the BMR Journal.

A.L. Jaques and G.P. Robinson wrote a paper for the BMR Journal on the continent-island arc collision in northern Papua New Guinea.

D.S. Hutchison completed work on the Aitape, Vanimo, Wewak, and Sepik 1:250 000 Sheets and their accompanying Explanatory Notes.

IRIAN JAYA PROJECT

by

R.J. Ryburn

STAFF: D.S. Trail (ADAB); R.J. Ryburn, G.P. Robinson, P.E. Pieters, D.S. Hutchison (resigned June); Staff of the Geological Survey of Indonesia.

INTRODUCTION

Since early 1975, when a request was received from the Indonesian Government for aid in earth resource management, BMR, the Department of National Resources and the Australian Development Assistance Bureau (ADAB formerly ADAA) have been preparing for a ten-year project to assist the Geological Survey of Indonesia, principally in systematic geological and geophysical surveys of Irian Jaya (Indonesia New Guinea). The Department of National Resources is to be the managing agency for the project, and full-scale fieldwork is expected to begin in 1978.

1976 RECONNAISSANCE

From August to November 1976, a combined party of BMR and GSI geologists undertook a reconnaissance of western Irian Jaya to determine the feasibility of the project and to gain familiarity with the terrain and the problems that would be encountered during full-scale surveys. However, geological observations were made as opportunity permitted, and the results of the reconnaissance include pilot stream-sediment geochemistry, airphoto interpretation, petrography, rock geochemistry, and reconnaissance K-Ar dating. Logistic support was provided by the Royal Australian Air Force and the Royal Australian Survey

Corps, which were engaged in aerial photography and ground-control surveys for the production of topographic maps. Use was also made of local air and sea transport.

The field research covered parts of the northern and eastern Birdshead (Kepala Burung), the Wandamen Peninsula, Gag Island and the Sorong and Karas areas (Fig. M16). Most of the party was based at Manokwari for two months, and a preliminary geological map of the 1:250 000 Manokwari Sheet area was produced as a result of the more intensive work in that area. Robinson later visited GSI headquarters in Bandung from March to May 1977, to help complete this map and the accompanying description, and to observe methods and facilities at the Geological Survey. Ratman, Masria and Kastowo visited BMR in June and July 1977,, to assist with follow-up work, observe BMR methods, and help plan the future of the project.

PRELIMINARY RESULTS

The following account is mainly a brief geological description of the Birdshead area, where systematic field research is planned to start in June 1978. It includes some of the results of the 1976 reconnaissance.

The Birdshead has a basement of folded Palaeozoic shales (Kemum Formation) that become progressively more metamorphosed to phyllite and schist towards the Arfak Mountain in the east. The shales contain Silurian graptolites in the west (Visser and Hermes, 1962) and Devonian ostracods further to the east (unpublished Pertamina report). Granitic plutons, which intrude the more highly metamorphosed sediments in the Arfak Mountains, were previously thought to be Devonian, but samples collected in 1976 yielded Late Permian to Early Triassic K-Ar ages (222-246 m.y.), very similar to those obtained from the Kubor Granodiorite in PNG (Page, 1976). Accessory minerals such as allanite, monazite, thorite, xenotime, and zircon give rise to radiometric anomalies in the alluvial deposits of streams draining the granites (d'Audretsch et al., 1966). Preliminary analyses indicate up to 6 ppm uranium and 12 ppm thorium in the granites.

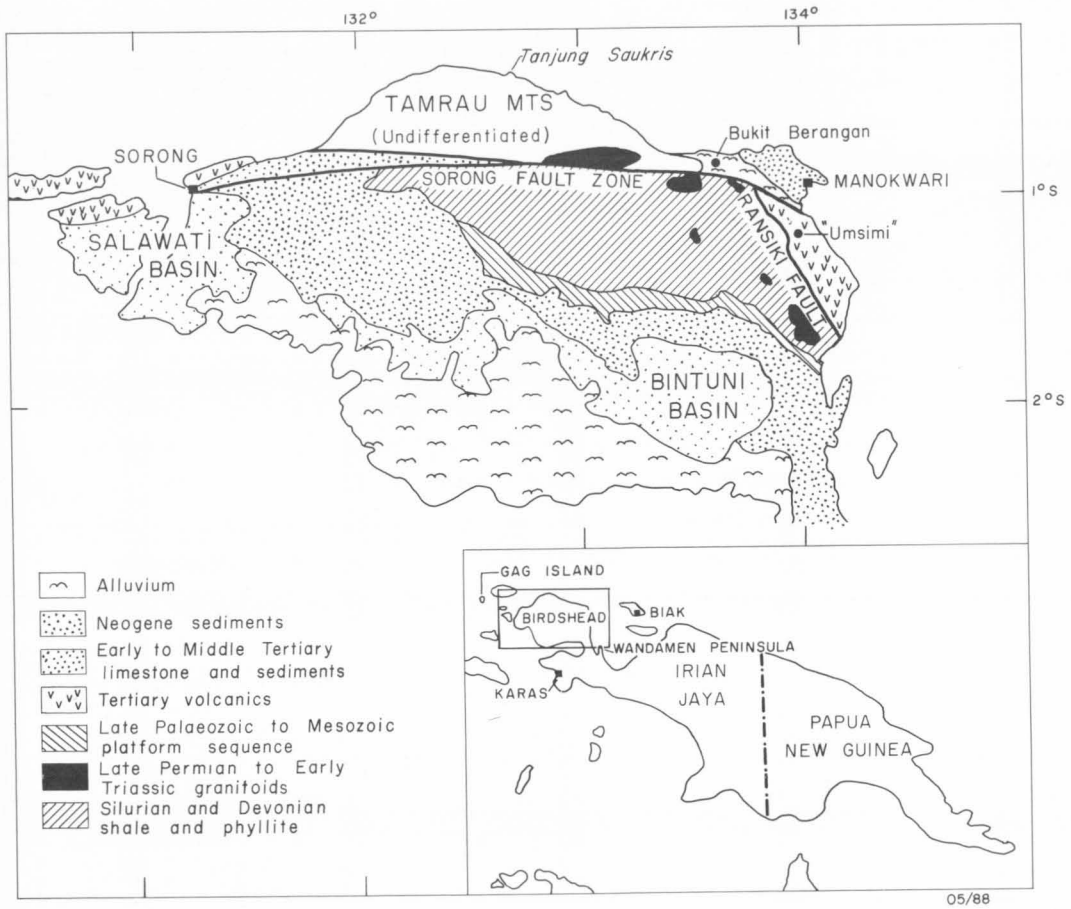


FIG.M16 Geological sketch map of the Birdshead, Irian Jaya

In the eastern Birdshead, Tertiary volcanics and volcaniclastics, believed to have been generated in an island arc environment, are faulted against the Palaeozoic basement by the Ransiki Fault. Similar volcanics occur along the north coast of the Birdshead. The northern Birdshead is cut by a major east-trending fault system, the Sorong Fault Zone, which is considered to have a large left-lateral displacement. Mid-Tertiary sediments and limestones are trapped in graben structures along this fault zone. A large monzonitic pluton north of the Sorong Fault Zone in the Kebar area is probably a correlative of the Permo-Triassic intrusives in the eastern Birdshead, and may indicate about 50 km sinistral displacement on the fault zone. In the Tamrau Mountains north of the Sorong Fault Zone the geology is complex; Palaeozoic, Mesozoic, and Tertiary rocks are all represented. Middle Miocene dioritic intrusives (15.4-16.2 m.y.) similar to those in PNG occur here and at the northern end of the Arfak Mountains. Ultramafic rocks are also present in the Tamrau Mountains.

In the southern and western Birdshead, the basement is unconformably overlain by a Permo-Carboniferous to Cretaceous platform sequence of mixed terrestrial and marine sediments. These are, in turn, overlain by a Lower to Middle Tertiary sequence of karst-forming limestones and clastics. Thick Neogene sequences containing petroleum reservoirs form the Salawati Basin in the west and the Bintuni Basin in the south. Oil is currently being produced from pinnacle reef reservoirs in the Salawati Basin.

The existence of "Umsimi Volcano", in the Arfak Mountains south of Manokwari, has long been a source of controversy in Indonesia. Observations from the air, and a ground traverse across the "volcano" strongly indicate that it is not a Quaternary volcano, but part of the Tertiary volcanic sequence in the area. However, Bukit Berangan, a dome-shaped hill on the north coast west of Manokwari, may in fact be a Quaternary eruptive centre. Unfortunately, basaltic scoria from here was unsuitable for K-Ar dating, and further material will need to be collected. Basaltic clasts from another eruptive centre at Tanjung (Point) Saukris, farther west, gave discordant whole-rock dates of 9.2 and 11.5 m.y.

In the Wandamen Peninsula, southeast of the Birdshead, regionally metamorphosed amphibolite facies gneisses yielded very young muscovite and biotite ages of about 3-4 m.y. The gneisses include metasediments, metabasic rocks, and orthogneisses which appear to be the metamorphosed equivalents of the Permo-Triassic granites in the Birdshead. Some of the metabasites are retrogressed (hydrated) eclogites, and the mineral paragenesis in the orthogneisses also indicate rather high pressures during metamorphism. It is probable that the Wandamen gneisses are part of the Tertiary high-pressure metamorphic belt along the northern fall of the central ranges of Irian Jaya and PNG. Uplift must have been very recent.

On Gag Island (a lateritic nickel prospect that lies to the west of the Birdshead), sheeted dolerite dykes were observed in association with the harzburgites on which the laterite is developed. Major and trace element analyses of the dolerites indicate that they are oceanic tholeiites. A single amphibole date of 148 $\pm$ 8 m.y. was obtained from a quartz-bearing dyke rock. The island is almost certainly exposed oceanic crust and upper mantle.

No major anomalies were located by the pilot stream sediment sampling program, which served to establish guidelines for future geochemical work.

PETROLOGICAL, GEOCHEMICAL, AND GEOCHRONOLOGICAL LABORATORIES

Supervising geologist: John Ferguson

STAFF: L.P. Black, B.I. Cruikshank, G.R. Ewers, D.J. Ellis (study leave), John Ferguson, A.Y. Glikson, A.D. Haldane, D.H. McColl (part time), C.M. Mock, R.W. Page, A.G. Rossiter, P.A. Scott, J.W. Sheraton, S.E. Smith

Technical Staff; G.W.R. Barnes, M.J. Bower, K.H. Ellingsen, J.L. Fitzsimmons, R. Flossman, N.C. Hyett, J.G. Pyke, T.I. Slezak, J.C.W. Weekes (to Oct), T.K. Zapasnik.

Trainee Technical Officers: N. Davis, J. Duggan, D. Johnstone, B. Jones, J. Purcell, G. Sparksman, R. Tracey, A. Warnes (all part-time variously throughout the year).

PETROLOGY LABORATORY

ALKALINE ULTRAMAFIC ROCK PROJECT by John Ferguson, J.W. Sheraton and L.P. Black

This project entails the study of kimberlites, carbonatites and other alkaline ultramafic rocks associated in space and time in eastern Australia. Petrochemical and age-dating studies have been carried out on the matrices, mineral concentrates, and inclusions found in a number of these diatremes. Most of the results of this work were presented at the Second International Kimberlite Conference, Santa Fe in early October. Three papers were presented which dealt with: petrochemistry of matrices and nodules (Ferguson and Sheraton), rare earth element (REE) study (F.A. Frey, Ferguson and B.W. Chappell) and the age and tectonic setting (K.J. Stracke, Ferguson and Black).

The REE study and pressure-temperature estimates based on the compositions of liquids in the CMAS tetrahedron and on coexisting mineral phases in xenoliths indicate that some of the eastern Australian kimberlites originated at depths in the 70-100 km range and were probably generated by small degrees of partial melting of garnet lherzolite in the upper mantle at temperatures around $1250^{o}C$. The abnormally high geothermal gradient implied by these data is higher than the calculated mean oceanic geotherm, and intersects the graphite-diamond stability curve at considerably higher temperatures and pressures than those indicated by the xenoliths, so that it is highly unlikely that diamondiferous kimberlite will be present in some areas of eastern Australia.

In an attempt to relate the kimberlitic intrusives and associated rock types to a structural framework the following features were investigated: on and off-shore linear structures, igneous activity, earthquake activity, general tectonics, gravity, and magnetics. It appears that postulated continental extensions of transform faults, stemming from both the Antarctic and Tasman Sea Ridges, have played the major role in the location of kimberlite intrusives in eastern Australia. Near the eastern seaboard, the NNE-projected continental fracture zone, stemming from the Antarctic Ridge, also coincides with a broad belt of Cainozoic igneous activity, an edge of epeirogenic uplift, and the mean line of hot-spot migration.

All of the kimberlitic occurrences near the eastern seaboard of Australia fall within this broad zone of activity. Their location also appears to have been governed by fracture patterns initially developed during pre-break-up times which later became the sites of continental extensions of transform faulting.

A study was completed on the basic inclusions from the Kayunnera kimberlitic breccia pipe, NSW (A.C. Edwards, J.F. Lovering and Ferguson). Two types of basic inclusions were found:

Type I comprise the assemblage:

clinopyroxene + garnet + rutile $\pm$ scapolite $\pm$ apatite

and

clinopyroxene + garnet + plagioclase $\pm$ quartz $\pm$ K-feldspar

Type II comprise the assemblage:

clinopyroxene + garnet + kyanite + quartz

and

clinopyroxene + garnet + plagioclase + kyanite + quartz

Comparison with experimental data and theoretical models demonstrates that these assemblages equilibrated at between 850-900^{o}C and 19-23 kb. The different mineral assemblage of the type I and II basic inclusions can be attributed to bulk-rock chemical constraints. The presence of sulphur-rich scapolite in these rocks extends the range of pressure conditions from which this mineral has been reported.

URANIUM MINERALISATION, PINE CREEK GEOSYNCLINE, NT by John Ferguson, G.R. Ewers, T.H. Donnelly (CSIRO) and G.W.R. Barnes

In order to assess the controls of uranium mineralisation in the Pine Creek Geosyncline (PCG) a broad petrochemical approach has been adopted. To this end all rock types within the geosyncline have been selectively sampled with particular emphasis being given to the areas of economic or potential economic uranium mineralisation. After detailed field and petrographic study 350 rocks were selected for bulk chemical analysis and each specimen analysed to a total of 43 elements. These analyses are now being statistically evaluated in order to assess correlation matrices. Where uranium is greater than 40 ppm in the rocks there is a positive correlation (at the 95 percent confidence

level) of U with Th, Pb, V, Zr, Nb, and W. Host rocks to the uranium mineralisation in the PCG are Lower Proterozoic sediments and metasediments, the provenance of which is the Archaean rocks. Relative to world abundances these Archaean granitoid rocks have a uranium enrichment factor of 3 to 4.

Stable isotope determinations of C, O, and S are being made on coexisting sulphides and/or carbonates and/or graphite from the uranium mineralised areas. Based on this study tentative temperature estimates of U-formation indicate values in the range 100^{o}-$260^{o}C$. Palaeoenvironmental conditions are also being assessed in the light of this study.

Activity diagrams and Eh-pH diagrams, which are based on the ore and gangue mineralogy of the East Alligator uranium deposits, and additionally make use of fluid inclusion and stable isotope data, have been constructed in an effort to define the physico-chemical constraints of ore formation. A preliminary analysis of these diagrams indicates that they will be of limited value since the opaque and silicate mineralogy in the ore zones is not sufficiently complex to define boundary conditions (for parameters such as fs_2, fo_2) with any precision. Also, for those minerals which are present, there are only limited thermodynamic data available. Some further information may be obtained from these diagrams if it can be established which minerals are in equilibrium and what the paragenetic sequence is within each deposit. This work is continuing.

It has been recognised by others that one of the most unifying aspects of the East Alligator deposits is the ubiquitous nature of chlorite and clays in the mineralised zones. These minerals vary in habit from cryptocrystalline to flaky, and form at least two generations. The different varieties of chlorite and clays in mineralised and unmineralised core material have been analysed with the electron microprobe to assess whether one particular composition of mineral is genetically related to the mineralisation. To this end, approximately 400 mineral analyses have been completed. These data are at present being processed.

An informal group of personnel from three organisations, known as the "Pine Creek Geosyncline Uranium Study Group" was formed to promote geological and geophysical investigation of uranium mineralisation within the Geosyncline. The three members of this group are J.C. Rowntree, Pancontinental Mining Limited, G.H. Taylor, CSIRO, and John Ferguson of BMR. An International Uranium Conference dealing with Lower Proterozoic

uranium deposits is being organised by this committee and it is proposed to hold this in Sydney in the latter half of 1978. It is planned to publish the Proceedings of the Conference.

During September Ferguson visited the major uranium deposits of Northern Saskatchewan, Canada, these being Cluff Lake, Key Lake, Rabbit Lake and Beaverlodge. In common with the uranium deposits of the PCG, the uranium is located near a major unconformity separating deformed Lower Proterozoic metasediments and relatively undeformed Middle Proterozoic sandstone. The Rabbit Lake deposit appears to bear the closest resemblance to the deposits in the Alligator Rivers uranium field.

PETROLOGY AND GEOCHEMISTRY OF IGNEOUS AND METAMORPHIC ROCKS FROM ANTARCTICA

by J.W. Sheraton, W.B. Dallwitz and D.J. Ellis

Petrographic and geochemical investigations of igneous and metamorphic rocks from Enderby Land continued in conjunction with the 1:250 000 scale geological investigation of the area. About 150 samples collected during the 1977 field season will be analysed for major and trace elements.

Sapphirine-bearing rocks

Dallwitz, Ellis, and Sheraton continued their investigations of aluminous metasediments containing the high-temperature assemblage sapphirine + quartz, and it is intended to prepare a paper on this topic. Coexisting sapphirine and quartz were found at several new localities during the 1977 field season, although none of the rocks yet examined contains the complex reaction relationships observed in those from the original locality. The most common retrograde reaction appears to be:

Sapphirine + Quartz → Cordierite

Most sapphirine grains have thin rims of cordierite adjacent to quartz. Further details of these rocks were given in the Geological Branch Summary of Activities for 1976 (BMR Report 196).

A number of occurrences of rocks containing the assemblage orthopyroxene + sapphirine $\pm$ spinel $\pm$ phlogopite $\pm$ cordierite were discovered. These rocks generally occur as pods or lenses a few metres across and are being studied in detail in an attempt to elucidate their origin.

Eclogites

Ellis (now on study leave at the University of Tasmania) is undertaking petrographic examination and electron microprobe analysis of eclogites which contain the assemblage clinopyroxene + garnet ± orthopyroxene ± hornblende. It is hoped to obtain estimates of the temperature and pressure of crystallisation from the compositions of coexisting minerals in these rocks.

Mafic dykes

At least five types of mafic to ultramafic dykes have been found in central Enderby Land. The oldest pyroxenite and mafic dykes are deformed and metamorphosed, and fresh dolerites are common. The dolerite dykes are mainly of quartz tholeiite composition and at least two varieties are present. The majority contain clinopyroxene with little or no orthopyroxene, but some contain abundant phenocrysts of orthopyroxene. The final group of dykes are alkali basalts which cut the dolerites, although only two (from a single locality) have been found. They contain alkali feldspar, plagioclase, biotite, and alkali amphibole, and apatite, and may be related to a magnophorite basalt dyke from Mount Bayliss in the southern Prince Charles Mountains.

Chemical analyses of these various dykes will be compared with those similar dykes from the Prince Charles Mountains and Vestfold Hills to see if any correlations with these areas are possible. The dykes provide one of the keys to deciphering the metamorphic history of Enderby Land because their relationships with episodes of deformation and the effects upon them of the various metamorphic events may be established.

Felsic Gneisses

The two most abundant groups of rocks in Enderby Land are a rather uniform series of orthopyroxene-quartz-feldspar gneisses, and a more strongly layered sequence of garnet-quartz-feldspar gneisses with associated aluminous, siliceous, and ferruginous metasediments. The orthopyroxene-quartz-feldspar gneisses are mostly of roughly granitic composition and are thought to have been derived by metamorphism of greywacke-type sediments or, more probably, acid volcanics. Some of the more massive varieties may be of intrusive igneous origin. The garnet-quartz-feldspar gneisses are almost certainly of sedimentary

origin. The geochemistry of these rocks will be investigated in order to obtain further evidence regarding their origin and metamorphic history. Comparisons will be made with granitic intrusives from various parts of Enderby Land and with similar gneisses from the Prince Charles Mountains and Mawson Coast. It is possible that the gneisses of central Enderby Land are the high-grade equivalents of the Archaean granitic basement rocks of the southern Prince Charles Mountains, and geochemical correlations between the two areas will be examined.

Gaussberg

The pillow lavas of Gaussberg on the Wilhelm II Land Coast consist of leucite basalt which contains phenocrysts of leucite, clinopyroxene, and olivine in a mainly glassy groundmass. Chemically they belong to the rare suite of ultrapotassic subvolcanic and volcanic rocks and have very high Ti, K, P, Rb, Sr, Zr, Ba, La, and Ce. Further geochemical investigations of these unusual rocks will be undertaken by Sheraton in cooperation with Dr A. Cundari of the University of Melbourne who will carry out rare-earth element analyses and experimental studies at atmospheric and high pressures.

PILBARA GEOCHEMICAL PROJECT by A.Y. Glikson and A.H. Hickman (Geol. Surv. W. Aust.).

The analytical geochemical work on the first three sample batches (35 samples, 201 samples, 235 samples), constituting stage 1 of the project, has been completed. The work included silicate analyses, CO_2, S, Ba, Ce, La, Mo, Nb, Pb, Rb, Sn, Sr, Th, U, V, Y, Zr, Ag, Be, Cd, Cr, Cu, Li, Ni, and Zn determinations.

The interpretation and writing up will be undertaken during 1978. Preliminary observations suggest some significant differences between the Pilbara and Yilgarn chemical data. Examples are the generally higher TiO_2 and lower Cr and Ni levels in tholeiites of the Pilbara; occurrence of high-Al andesites in the Talga-Talga Subgroup (Pilbara) - a rock type rare in the Yilgarn; abundance of high-Mg komatiites and scarcity of peridotitic komatiites in the Pilbara; occurrence of some potassic rhyolites in the Duffer Formation, which otherwise consists mainly of dacitic agglomerates. The degree of alteration is in many instances relatively minor.

Recent advances in isotopic dating of Pilbara volcanics and associated rocks, including Pb model and zircon ages, now indicate an age in excess of 3.5 b.y. for the Talga-Talga Subgroup. This succession is, as mapped by Hickman, in places over 5 km thick, and is widely distributed in the Pilbara as both circum-batholithic veneers (intruded by or faulted against the granites) and trains of xenoliths. It is suggested that these represent the relicts of a shield-wide volcanic-sedimentary layer, or crust, for which no maximum isotopic age is as yet established. The possibility that these supracrustal rocks are of similar age to volcanic units in the oldest Archaean terrains - i.e., Greenland, Labrador, Minnesota - remains a subject of further zircon studies, currently being carried out by R. Pidgeon (ANU). It has been suggested earlier by D.H. Green and by Glikson that the early greenstones may have been genetically related to the extraterrestrial meteorite bombardment phase during 4.1-3.9 b.y. ago, as inferred from lunar studies.

EARLY CRUSTAL EVOLUTION by A.Y. Glikson

An invitation was received from J.A. Hallberg (CSIRO) to jointly write a chapter entitled "Archaean granite-greenstone terrains of Western Australia" as a contribution to a volume edited by D.R. Hunter (University of Natal) and entitled "Precambrian of the Southern Continents". The manuscript is now complete, apart from the drafting of some maps, and presents a comprehensive up-to-date account of the present state of knowledge on the Yilgarn and Pilbara cratons. One outcome was a remarkable degree of agreement concerning the interpretation of several aspects of Archaean evolution.

An invitation has been also received from F. Barker, US Geological Survey, Denver, to contribute a chapter on Archaean tonalites and granodiorites for a book on "Trondhjemites, Dacites and Related Rocks". At present the material for this paper has been assembled, and the writing should be complete before the end of the year.

During the year two discussion papers were published and one submitted, concerning aspects of early crustal development in Rhodesia, Labrador and Canada. The first, entitled "Vestiges of a beginning", was written in response to a discussion letter by Nisbet and Bickle (Universities of Oxford and Leeds), based on their experience in the Belingwe greenstone belt, Rhodesia. The second was submitted in connection with a paper by Bridgwater and Collerson

entitled "The major characteristics of the 3.6 b.y. old Uivak Gneiss, Labrador". This discussion, entitled "On the origin of early Archaean gneisses" questioned some of the conclusions of these authors, in the light of evidence from batholiths of granite-greenstone terrains. The third discussion, submitted to Canadian Geoscience, is entitled "On the basement of Keewatin greenstone belts". It discusses the conclusion of Baragar and McGlynn, who inferred a worldwide sialic basement beneath greenstone belts. The three discussions, if not leading to agreement, have served to increase the mutual understanding of conflicting points of view. Significant differences remain between the models of Archaean evolution arising from studies in the North Atlantic, Canadian, South African and Australian shields.

An invitation was received from Prof. A.J. Baer, University of Ottawa, to visit his department and submit 5 seminars to students and staff. Prof. Baer also organised a conference on "Granite-greenstones" to which some 50 North American geologists were invited. One week was spent on a joint trip with geologists of the Geological Survey of Canada in the Abitibi area, examining greenstones.

On the invitation of K.A.W. Crook, a paper entitled "Archaean history of the Australasian Plate" was read during the 48th ANZAAS Congress in Melbourne, in a symposium on the history of the Australasian plate.

PRECAMBRIAN EARTH RADIUS by A.Y. Glikson

In a paper submitted in 1974 at Newfoundland (in the symposium on Metallogeny and Plate Tectonics, St Johns), and published in 1976, entitled: "Archaean to early Proterozoic shield structures: relevance of plate tectonics" it was suggested, among other items, that the continuity of the Proterozoic sialic crust, and the lack of evidence for the nature of some 3/4 of the contemporary crust (during 2.6-1.0 b.y. ago), lend support to the expanding Earth hypothesis. Early in 1977 a conference was held in Hobart in honour of Prof. S.W. Carey - one of the foremost advocates of Earth expansion - entitled: "Creativity and Orthodoxy at the Frontiers of Earth Science". A paper was read, entitled: "Evidence for a small radius Precambrian Earth". Following the conference it was proposed to put down the arguments concerning this idea in writing, resulting in the paper: "Precambrian sial-sima distribution patterns: evidence for Earth expansion", now accepted for publication. A summary of the concept, entitled "Evidence on the radius of the Precambrian Earth" appeared in the BMR Journal.

It is shown that an explanation of the Early to Middle Proterozoic crustal record cannot be achieved if an Earth of present-day surface dimensions is assumed. With few exceptions, lithostratigraphic, geochemical, and isotopic data for the 2.6-1.0 b.y. time range are indicative of ensialic crustal environments, disclosing little evidence for contemporaneous sima or two-stage mantle melting processes. The relations between the Proterozoic mobile belts and the Archaean basement allow their three-fold classification in terms of intercratonic, marginal, and external mobile belts. It is clear that, in all documented instances, all the three types formed above sialic crust, and no evidence for oceanic sutures is at hand. Ophiolites are unknown and ocean-floor or arc-trench type assemblages are rare in these terrains. The essential integrity of the Early to Middle Proterozoic sialic crust, suggested by both geological and palaeomagnetic evidence, requires that, on an Earth of present-day dimensions, had simatic crust existed it must have occupied a vast hemisphere-size regime. It is calculated that the operation of seafloor spreading, subduction, and partial melting processes within and along the margins of this regime should have given rise to at least 500 x 10^6 km^3 of sima-derived materials, but no record is observed of such vast belts. The isotopic evolution of carbonates and K/Na ratios in clastic sediments militate against extensive distribution of sima and its fusion products during 2.6-0.6 b.y. ago. Unless all evidence for such crust has been inexplicably eliminated, global sial is deduced for this time span. However, the sial budget in the present-day crust does not allow such a global crust to have been of normal continental thickness, and an existence of a thin sial and its subsequent accretion into the present continental crust is negated by palaeomagnetic and structural data. An enigma thus arises regarding the nature of 3/4 of the crust during the Lower and Middle Proterozoic, which cannot be explained on an Earth of present-day dimensions, but is fully explicable had the surface area grown with time, in agreement with the expanding Earth hypothesis. The appearance of ophiolites and calcalkaline volcanic suites about 1.0 b.y. ago signifies an onset of plate tectonics - the manifestation of seafloor spreading and expansion. It is estimated that the radius of the Earth prior to that stage was about or less than 50 percent of the present-day radius.

INSTRUMENT LABORATORIES AND SUPPORTING FACILITIES by G.W.R. Barnes and R. Flossman.

Rock Sectioning (R. Flossman).

The following were completed: five hundred and twenty nine thin sections, four hundred polished thin sections, fourteen large thin sections and six polished sections.

Field activities undertaken during the year included kimberlite and nodule collecting with John Ferguson and an extended visit with the Museum Party to make mineral collections at the Brown's base metal deposit at Rum Jungle, NT.

The Logitech Automatic Thin Section machine was given an extended demonstration under BMR supervision and proved to be a most useful instrument.

X-ray Diffraction (G.W.R. Barnes)

2130 samples were analysed by X-ray diffraction.

85% of the total work load was devoted to 7 BMR projects, including:

South Australian coastal studies mineralogy (J.B. Colwell) 1225 samples;

Phosphate Group aragonite/calcium carbonate studies (P.J. Davies & J.F. Marshall) 300 samples;

Baas Becking sulphur isotope and other studies (I.B. Lambert & P.J. Davies), 125 samples;

Baas Becking experimental carbonate mineralogy (B. Bubela, Jim Ferguson, & P.J. Davies) 90 samples;

Museum mineral collections (D.H. McColl), 55 samples;

Spencer Gulf study (R.V. Burne), 18 samples; and

Petroleum Technology kerogen studies (D.M. McKirdy & Z. Horvath), 17 samples.

Installation of the computer link by the BMR ADP section to the XRD commenced early in 1977, but to date no further work has been done. It is hoped that the installation and interface can be completed by the end of 1978.

A graphite monochromator has been purchased and installed, and is proving very satisfactory.

GEOCHEMISTRY LABORATORY

REGIONAL STEAM-SEDIMENT SURVEYS, QLD AND NT by A.G. Rossiter and P.A. Scott

Regional stream-sediment geochemical surveys are undertaken by BMR to assist in the evaluation of the mineral potential of selected areas by a study of the distribution of anomalous concentrations of various trace elements within a region.

As part of this objective over 6000 samples were collected during the period 1974-76 from five 1:100 000 Sheet areas in the Georgetown and Westmoreland regions. This work was reported in the Annual Summary of Activities, 1976. No further field work was undertaken this year; instead activities have been directed to refining an information storage/retrieval system and a computer-assisted cartography system to process the large amount of field and laboratory data generated by the previous two years' sampling. These systems are now working successfully.

Progress to date on the various Sheet areas sampled is detailed in Figure M17. The Forsayth 1:100 000 geochemical map series which is now ready for printing consists of 5 maps each combining analytical values for a group of three elements as follows: copper-cobalt-nickel, copper-lead-zinc, uranium-cerium-thorium, uranium-arsenic-bismuth, tin-niobium-tungsten. The format of the maps is illustrated in Figure M18. A record to accompany the Forsayth maps has been prepared.

The ultimate aim of these programs is to delineate broad areas where future detailed exploration should be concentrated. The Forsayth survey appears to have done this most effectively, and results suggest that the area's greatest economic potential lies in the possibility of tin and uranium deposits in the Newcastle Range Volcanics and uranium mineralisation in alteration zones in the Robin Hood Granodiorite.

GEOCHEMISTRY OF THE CULLEN GRANITE, NT by G.R. Ewers and P.A. Scott

This project commenced in mid-1975 with the objectives of providing information on the overall geochemistry of the Cullen Granite, including the relationships between the various phases of the granite. It was also hoped to establish the relationship between the geochemistry of the granite and mineralisation contained within the granite and surrounding sedimentary rocks.

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)													

AUS 2/457

FIG.M17 Current status of BMR's regional stream - sediment surveys

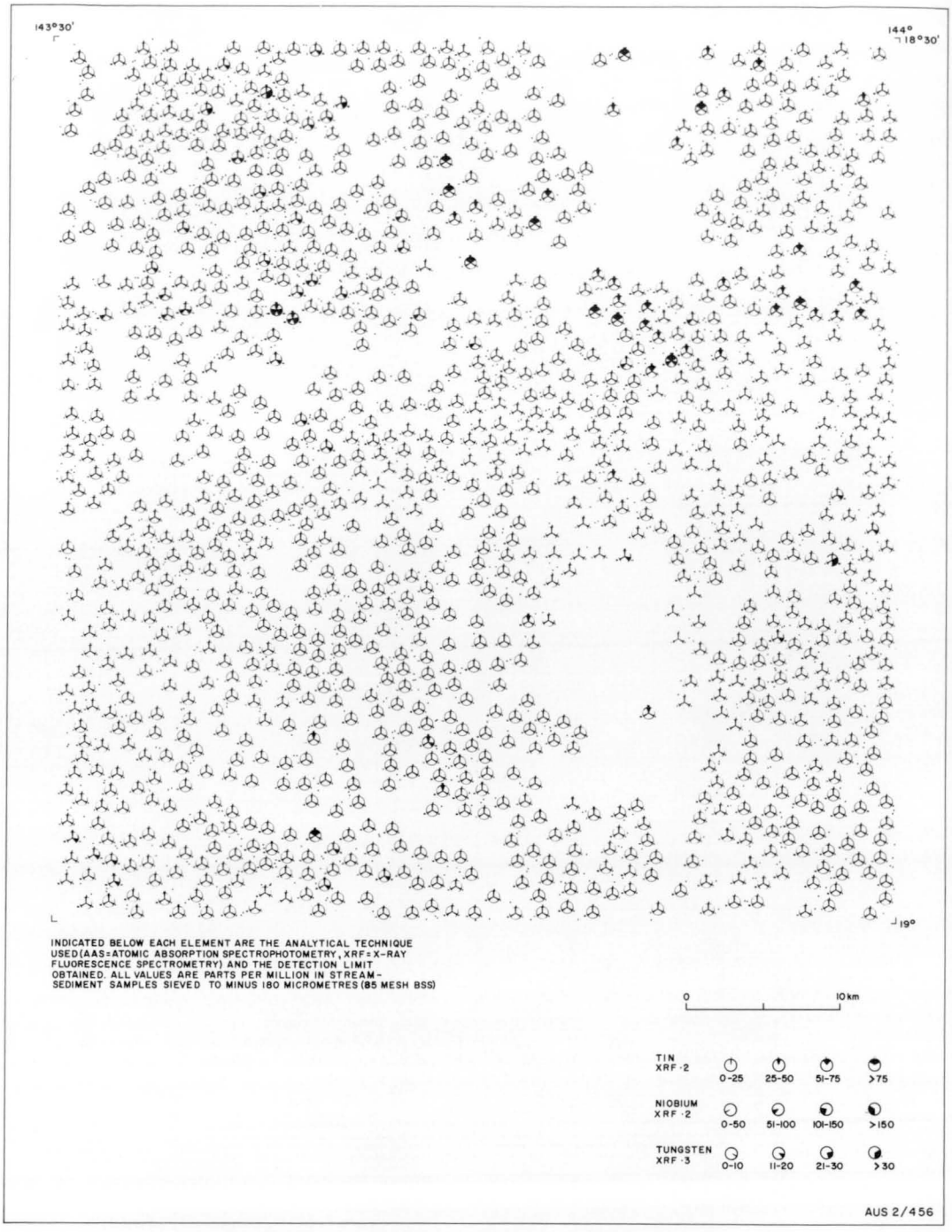


FIG. M18 Computer-drafted plot of the Forsayth 1:100 000 Sheet area showing results for tin, niobium and tungsten in stream-sediment samples. A topographic base will be added during printing of the final maps. Numerous tin anomalies in the northeast of the sheet area are associated with rocks of the Newcastle Range volcanics

Laboratory results support field observations in that they indicate that one of the five phases of granite identified is younger and more highly fractionated than the rest. However, the existence of a relation between the granite geochemistry and mineralisation is suggested by only a few trace elements (U, Cu, W). The well-documented tendency for the Sn content of intrusive rocks associated with Sn deposits to be higher than those rocks without deposits is not supported by the Cullen Granite data. Although numerous Sn deposits occur in and around the granite, its Sn content is near or below the limit of detection.

This project has now been completed and the findings have been published in a recent issue of the BMR Journal (Ewers and Scott, 1977).

POLLUTION STUDIES IN THE MOLONGLO RIVER, ACT by A.D. Haldane

Remedial measures to reshape, seal, and revegetate the mine waste dumps at Lake George Mine, Captains Flat, were completed by late December 1976. The results of monitoring specific conductance, pH, and zinc levels in the river between the ACT border at Burbong and Scrivener Dam indicates a substantial improvement in water quality. Further monitoring is in progress and a final report by the Joint Government Technical Committee is expected by mid-1978.

GEOCHEMISTRY OF THE TENNANT CREEK GOLDFIELD by A.D. Haldane and S.E. Smith

This project continues from previous years and was reported at length in the Annual Summary from 1976. Most of the work this year has been concerned with reduction and interpretation of the chemical data for the ironstone samples. All data for both silicate and ironstone samples were transferred to punch cards for computer handling, and suitable programs were modified for statistical analysis of the data. Statistical techniques based on a Gaussian distribution are not well suited to this project; ranking methods have problems. In particular, significant inter-element correlations appear to increase with increasing sample size, thus obscuring their interpretation. A summary of the draft report on the ironstones is as follows:

Magnetite-chlorite bodies

The magnetite-chlorite ironstones consist of magnetite and chlorite, with hematite, quartz, jasper, talc, dolomite, pyrite, pyrrhotite, and chalcopyrite often present. The chemical results show that iron and silicon are the main elements present but that aluminium and magnesium are also present in major amounts. Calcium, manganese, phosphorus, potassium, and titanium are usually present in small amounts but some higher values of calcium, phosphorus, and potassium were obtained. The calcium is present in apatite, dolomite and tremolite-actinolite; phosphorus in apatite and potassium in muscovite. High values of Ag (to 16 ppm), Bi (to 9500 ppm), Co (to 800 ppm), Cu (to 8%), Mo (to 5000 ppm), Pb (to 6500 ppm), and Zn (to 1.5%) were obtained.

Element correlation matrices showed associations between Pb and Zn; Ag, Co, and Cu; Pb and Bi; Al, Ti, and Cr; Mg and Al; Ti and K; and Si and Mg.

Hematite-quartz bodies

The main constituents of these ironstones are hematite, quartz, and jasper in varying proportions. Magnetite, goethite, and clay are commonly present in small amounts. Fe_2O_3 + SiO_2 make up more than 98% of the composition of the rock. Aluminium is the next most abundant element with a mean average of 0.7% Al_2O_3; it is present mainly as kaolinite.

In general calcium, magnesium, manganese, phosphorus, potassium, and titanium are present in small amounts. However, some samples do contain moderate to high amounts of manganese, phosphorus, or potassium. Manganese is present as pyrolusite, and potassium as muscovite. The phosphorus mineral could not be identified but as iron was the only cation present it is likely to be a variety of ferric phosphate.

At times high values of Ag (to 15 ppm), Bi (to 1%), Co (to 500 ppm), Cu (to 8000 ppm), Mo (to 1300 ppm), Pb (to 4000 ppm), and Zn (to 2000 ppm) were present. Element correlation matrices showed an association between Ag and Bi; Cu, Pb, and Zn.

A study of the distribution of anomalous values of Bi, Cu, Pb, and Zn showed that they corresponded to the distribution of the major gold mines. It appears that the widespread gold mineralisation in the area was accompanied by traces of Bi, Cu, Pb, and Zn. Consequently these elements may well be useful as indicators of gold mineralisation. This is an important point, as early workers felt that the presence of anomalous copper values indicated the presence of copper mineralisation.

MARY KATHLEEN URANIUM: SOLID-SOLUTION EQUILIBRIA STUDY by B.I. Cruikshank, John Ferguson and G.M. Derrick.

The Mary Kathleen uranium deposit in northwest Queensland is contained in folded Middle Proterozoic metasediments of the Corella Formation. The dominantly calcareous rocks in this Formation were metamorphosed to hornblende hornfels facies during granite intrusion, producing calc-silicate and marble assemblages. A later metasomatising event, which was also responsible for the uranium mineralisation in the area, has resulted in skarn replacement of the earlier metamorphosed rocks. In order to evaluate and quantify the metasomatic history associated with the uranium mineralisation an extensive sampling and field work program was undertaken in 1976 and 1977 to supplement earlier studies in the region (Derrick, 1977).

Whole-rock chemical analyses have been completed on the suite of rocks selected and reveal the following changes:

	Introduced elements	Removed elements
Marble to skarn	*Si, Ti, Al, Fe^{2+}, Fe^{3+} Mn, U, rare earth elements (REE)	Mg, Ca, K, C
Calc-silicates to skarn	Fe^{3+}, Mn, U, REE	Mg, Na, K, C

*Using Student's "t" test, significant at the 95 percent confidence limit.

Mineralogical changes include:
grossular garnet and diopside in the calc-silicates and marbles become andraditic and hedenbergitic in the skarn rocks respectively.

ANALYTICAL LABORATORIES AND SUPPORTING FACILITIES by B.I. Cruikshank

STAFF: B.I. Cruikshank, K.H. Ellingsen, G.R. Ewers, J.L. Fitzsimmons, J.G. Pyke, T.I. Slezak, J.C.W. Weekes (to Oct.).

Projects receiving analytical support included the Georgetown and Westmoreland geochemical surveys, Alligator Rivers geochemistry, Arunta/Pilbara geochemistry and Antarctic geochemistry. Although these projects provided the bulk of the samples analysed in the laboratory, a number of smaller projects were supported as resources permitted.

Although plagued by equipment failures (fume cupboards, instrument breakdowns, etc.), the laboratory processed about 5200 samples for a total of 70 600 element determinations.

X-Ray Fluorescence Spectrometry

Both spectrometers suffered considerable downtime, the PW1450 being unserviceable for a total of about five months. However, 527 samples from the Arunta, Pilbara, Alligator Rivers, Mary Kathleen, and Redbank projects were analysed on the major-element program (5270 element determinations).

Trace elements were determined on 4960 samples (52 550 element determinations), mostly from the Georgetown and Westmoreland geochemical surveys and the Arunta, Pilbara, and Alligator Rivers geochemical projects.

Atomic Absorption Spectrophotometry

Despite continued problems with the spectrophotometer-computer interface (requiring replacement) and failure of the laboratory's fume cupboards, 2450 samples were analysed (12 700 element determinations), mostly from the projects listed above.

Miscellaneous Determinations

Also analysed were 157 samples for FeO, comprising Mary Kathleen and Alligator Rivers samples, and 78 water samples from the Molonglo River.

GEOCHRONOLOGY LABORATORY

STAFF: L.P. Black, M.J. Bower, J.L. Duggan, N.C. Hyett, R.W. Page, T.K. Zapasnik

The Geochronology Laboratory continued to use the joint isotope laboratory facilities in the Research School of Earth Sciences, ANU. It is appropriate to acknowledge the further cooperation and assistance from the Director and Staff of the School in our activities.

Rb-Sr dating work continued during the year along lines of projects established in the previous Annual Summary (1976). Five of the projects were written up for publication in the BMR Journal or in outside journals. The chemical laboratory and the rock crushing/mineral separation laboratory were both entirely reconstructed, and hence were unproductive for almost half of the year. This reconstruction and the installation of some new equipment will provide excellent facilities for on-going Rb-Sr work and the recently commenced U-Pb zircon studies.

In the chemical laboratory, ultra-clean water and acid reagents are now routinely produced. Analyses of U and Pb standards, spike calibration runs, and blank analyses on individual reagents and on the total processing have been undertaken. In addition, four zircon fractions (previously analysed in Washington) have been isotopically measured. The overall Pb processing blank is gratifyingly low, at less than 1×10^{-9} g per analysis. This achievement is a pre-requisite for meaningful zircon geochronology which is to be carried out in several BMR project areas.

MOUNT ISA PROJECT by R.W. Page

No new ages were measured during the year. Field work in the area was aimed at further quantifying the stratigraphy of the eastern and western successions and intrusive granites, and samples were collected for U-Pb zircon work from most of the units previously worked upon by the Rb-Sr method. These include the Ewen Granite and associated volcanics, Weberra Granite, Fiery Creek Volcanics, May Downs Gneiss, four phases of Sybella Granite, Yaringa Metamorphics, Naraku Granite, three phases of Burstall Granite, Tommy Creek Microgranite, Eastern Creek Volcanics, Rifle Creek beds, and Mount Isa Group (Urquhart Shale).

TENNANT CREEK BLOCK by L.P. Black

The Rb-Sr study of the Tennant Creek Block was written up in the BMR Journal. The oldest documented event is amphibolite facies metamorphism of possible basement rocks at 1920 ± 60 m.y. The lower-grade metamorphic rocks of the Warramunga Group were deposited before the major deformation episode which is inferred to have occurred at about 1810 m.y. Some total-rock isotopic systems within the Warramunga Group (e.g. the Bernborough Volcanics) were reset during subsequent deformation. Granite ages range from 1800 m.y. for a phase of the Tennant Creek Granite to less than 1500 m.y. for the Cabbage Gum and Gone River East Granites. Dated lamprophyre and porphyry samples yield ages of about 1660 m.y. and 1760 m.y., respectively. Muscovite separates from the Juno, Warrego, Golden Forty, and Nobles Nob mines indicate a common origin for the ore deposits about 1810 m.y. ago.

ARUNTA BLOCK by L.P. Black

41 isotopic analyses for Rb and Sr were made on samples which were collected several years ago. The data have yet to be analysed in detail.

ALKALINE ULTRAMAFIC PROJECT by L.P. Black

17 total-rock and mineral separates were isotopically analysed for Rb and Sr. The data, when combined with those of the previous year, indicate that kimberlite emplacement in the eastern half of Australia was not confined to a single event. Isotopic data from the Jugiong pipes are not conclusive, but are nevertheless consistent with the stratigraphic constraints in indicating a Cainozoic age. Phlogopite separates yield Rb-Sr and a K-Ar age of about 174 m.y. (Jurassic) for some kimberlites in South Australia. Kimberlites at White Cliffs in western NSW are still older. Their Permian age has been derived from phlogopite (260 m.y.) within the kimberlite itself, and from a limiting maximum value of 260 ± 67 m.y. for an eclogite xenolith within the kimberlite.

WESTERN TASMANIA PROJECT by L.P. Black

Further samples were collected for U-Pb zircon dating from the Mount Read Volcanics. It is hoped that this technique will yield the time of crystallisation for these rocks. Previous Rb-Sr work yielded only post-crystallisation ages.

HERBERTON-MOUNT GARNET AREA by L.P. Black

The study of mineralised samples in the Herberton-Mount Garnet area was completed by the analysis of a further 3 samples to those analysed in previous years; a preliminary manuscript has been prepared. The Rb-Sr data reveal a close temporal association between ore deposits and major granitic activity in this area. Several mineralising events have been detected. The first, at 314 m.y. was associated with Elizabeth Creek Granite in the Emuford-Irvinebank area. A slightly, but significantly later event at 309 m.y. relates to petrographically similar Elizabeth Creek Granite in the Herberton area. Both these early events are characterised by greisen formation. A subsequent mineralisation at about 297 m.y. which is characterised by chloritic alteration, relates to a petrographically distinct fine-grained phase of the Elizabeth Creek Granite. The last hydrothermal alteration, producing fine-grained green biotite, occurred at about 284 m.y. and is apparently related to the Mareeba Granite. Sn deposits formed at each event. W may relate only to the earliest Elizabetn Creek Granite. Cu was associated with at least the first three events. Pb deposits also formed at more than one time.

GEORGETOWN INLIER by L.P. Black

A total of 62 samples were isotopically analysed for Rb and Sr during the year. Analyses of the Newcastle Range Volcanics are now complete but the data have yet to be assessed. Preliminary Rb-Sr data were obtained on the Forsayth, Robin Hood, and Mount Hogan Granites. The Forsayth Granite was further sampled for Rb-Sr work and also for U-Pb zircon work during the field season. Samples for zircon dating were also taken from the Robin Hood Granite. A suite of samples was also collected from the Barnard Metamorphics in an attempt to date the highest-grade and possibly oldest rocks in the northern part of the Tasman Geosyncline.

The isotopic study of the metamorphics from the Georgetown Inlier has been successfully completed. A sequence of five major, temporally discrete, regional structural events is established at 1570, 1470, 970, 400 and 300 m.y. The data reveal that Rb-Sr isotopic systems are reset over the scale of a cubic metre during penetrative schistosity-forming events.

ENDERBY LAND, ANTARCTICA by L.P. Black

A field-training program was attended at Rocky Valley in the Victorian Alps and an orientation week arranged by ANARE in Melbourne in preparation for the Antarctic field season commencing this December. Background reading was carried out and potential sampling sites selected.

MISCELLANEOUS ACTIVITIES

OVERSEAS VISIT: D.H. BLAKE TO THE GEOLOGICAL SURVEY OF CANADA (GSC)

by

D.H. Blake

After completing a 12-month exchange visit with the Precambrian Subdivision, Regional and Economic Division, GSC, based in Ottawa, D.H. Blake returned to BMR, Canberra, in May. While in Canada he continued his work on the Proterozoic Dubawnt Group, particularly the potassium-rich alkaline volcanics which have some associated uranium and minor copper, gold and silver mineralisation. Reports were prepared for the 1976 Canadian contribution to the IUGG and the GSC 1976 Report of Activities (Paper 77-1A). Blake also gave two talks to the GSC in Ottawa (on Papua New Guinea volcanoes and geology of The Granites-Tanami region), went on a four-day GSC field trip to the Sudbury area, Ontario, visited the GSC regional office in Vancouver, and took part in GSC/DNA (Department of Northern Affairs) Geoscience Forums at Whitehorse (Yukon Territory) and Yellowknife (NWT); at the latter forum he gave a paper on the Dubawnt Group rocks. On his way back to Australia he attended the 1977 Annual Meeting of the Geological Association of Canada in Vancouver; at this meeting he presented two joint author papers dealing with the volcanics of the Dubawnt Group.

APPENDIX

PUBLICATIONS AND RECORDS

Set out below are lists of publications and Records (unpublished reports) prepared in the Geological Branch during the year. They are divided into the following categories:

Bulletins: Published or in press
: With editors

Reports : Published
: With editors

Mineral Resources Reports

BMR Journal of Australian Geology and Geophysics
: Published or in press
: With editor

Outside Publications

: Published or in press
: Submitted or in preparation (for BMR authors 'in preparation' means that the paper is with editors)

Explanatory Notes and Maps

: Published or in press
: With editors

1:100 000 Maps : Preliminary editions issued or in preparation
: First Edition printed

Special Maps : Published or in press
: With editors
: Preliminary edition issued

Records : Issued
: With editors
: In preparation (being edited within the Geological Branch)

BMR Technical Notes

* Indicates that the publication is in the second of the categories shown in the heading.

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.

BULLETINS

PUBLISHED OR IN PRESS*

	151	NORVICK, M.S. BURGER, D.	Palynology of the Cenomanian of Bathurst Island, Northern Territory, Australia.
	162	PAGE, R.W.	Geochronology of igneous and metamorphic rocks in the New Guinea Highlands.
	163	MARSHALL, J.F.	Marine geology of the Capricorn Channel area.
*	167	SENIOR, B.R. MOND, A. HARRISON, P.L.	Geology of the Eromanga Basin.
	168	SWEET, I.P.	The Precambrian geology of the Victoria River region, Northern Territory.
*	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.	Sedimentation in a tropical estuary, Broad Sound, Queensland.
*	171	[5]POJETA, J. Jr GILBERT-TOMLINSON, J. SHERGOLD, J.H.	Cambrian and Ordovician rostroconch molluscs from northern Australia.

*	174	[5]POJETA, J. Jr GILBERT-TOMLINSON, J.	Australian Ordovician pelecypod molluscs.
*	177	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 - Genoa River (Mallacoota Inlet, Victoria).
*	192	BELFORD, D.J.	The genus Triplasia (Foraminiferida) from the Miocene of Papua New Guinea.
*	192	DICKINS, J.M.	Relationship of Mourlonia and Ptychomphalina, upper Palaeozoic Gastropoda.
*	192	KEMP, E.M.	Microfossils of fungal origin from Tertiary sediments on the Ninety-east Ridge.
*	192	SHAFIK, S.	Paleocene and Eocene nannofossils from the Kings Park Formation, Perth Basin, Western Australia.
*	193	DERRICK, G.M. [2]WILSON, I.H. HILL, R.M. GLIKSON, A.Y. MITCHELL, J.E.	Geology of Mary Kathleen 1:100 000 Sheet area, northwest Queensland.

*	194	HOHNEN, P.D.	Geology of New Ireland, PNG.
*	201	DOW, D.B.	Geological synthesis of Papua New Guinea (Notes to accompany 1:2.5M map).

WITH EDITORS

172	OPIK, A.A.	Middle Cambrian Agnostacea.
182	[1]COOK, P.J. [1]MAYO, W.	Geochemistry of a tropical estuary (Broad Sound, Queensland).
195	DAVIES, P.J.	Marine geology of the continental shelf of southeast Australia.
200	DRUCE, E.C. RADKE, B.M.	Geology of the Fairfield Group, Canning Basin, WA.
	BLAKE, D.H. HODGSON, I.M. [2]MUHLING, P.C.	Geology of The Granites-Tanami region, Northern Territory and Western Australia.
	BURGER, D.	Palynological studies in the Cretaceous of the Surat Basin, Australia.
	[4]TASCH, P.	Permian and Triassic Conchostraca from the Bowen Basin (with a note on a Carboniferous leaiid from the Drummond Basin), Queensland.
	[4]TASCH, P. JONES, P.J.	Lower Triassic Conchostraca from the Bonaparte Gulf Basin, north-western Australia (with a note on Cyzicus (Euestheria) minuta ? from the Carnarvon Basin).

TASCH, P. JONES, P.J.	Carboniferous and Triassic Conchostraca from the Canning Basin, Western Australia.
SHERGOLD, J.H.	Late Cambrian trilobites from the Chatsworth Limestone, western Queensland.
WELLS, A.T.	Evaporites in Australia.
BURGER, D.	Palynological studies in the Carpentaria Basin, Queensland, Australia.
NICOLL, R.S. DRUCE, E.C.	Conodonts from the Fairfield Group, Canning Basin, Western Australia.
SKWARKO, S.K.	Mesozoic molluscs from Papua New Guinea and northern Australia (eight papers awaiting Branch approval).
SMART, J. [2]GRIMES, K.G. DOUTCH, H.F. PINCHIN, J.	The Mesozoic Carpentaria and Cainozoic Karumba Basins, Queensland.

REPORTS

PUBLISHED

	173	BURTON, G.M. (Deceased)	Recharge conditions and the siting of bores in fractured rock aquifers of the ACT.
	188	JOHNSON, R.W.	Distribution and major-element' chemistry of late Cainozoic volcanoes at the southern margin of the Bismarck Sea, Papua New Guinea.
*	200	BLACK, L.P.	Isotopic ages of rocks from the Georgetown-Mount Garnet-Herberton area, north Queensland.
*	202	DRUCE, E.C. RADKE, B.M.	Geochemistry of the Fairfield Group, Canning Basin, WA.
*	195	[4]DE DECKKER, P. JONES, P.J.	Check list of Ostracoda recorded from Australia and Papua New Guinea (1845-1973).
*		SKWARKO, S.K.	Stratigraphic tables, Papua New Guinea.

WITH EDITORS

	ANON (Article co-ordinated by, and with contribution from E.K. Carter; other authors-J.C. ERSKINE, R.J. RYBURN, G.A. YOUNG, G. JACOBSON, D.C. PURCELL)	Foreign Aid (awaiting Branch approval)

DRUCE, E.C. SHERGOLD, J.H.	Annotated bibliography and index of the Georgina Basin, Northern Territory and Queensland.
GLIKSON, A.Y. DERRICK, G.M.	Geology and geochemistry of Middle Proterozoic basic volcanic belts, Mount Isa/Cloncurry, northwest Queensland.

MINERAL RESOURCES REPORTS

EDITED, AWAITING STATE/COMPANY COMMENTS

8	KNIGHT, N.D.	Antimony Deposits
9	KNIGHT, N.D.	Molybdenum Deposits

BMR JOURNAL OF AUSTRALIAN GEOLOGY AND GEOPHYSICS

PUBLISHED OR IN PRESS*

1(4)	NEEDHAM, R.S. STUART-SMITH, P.G.	The Cahill Formation - host to uranium deposits in the Alligator Rivers Uranium Field, Australia.
1(4)	JACOBSON, G.	The freshwater lens on Home Island Cocos (Keeling) Islands.
1(4)	KENNARD, J.M.	A sandstone breccia formed by quasi-liquid deformation from the Amadeus Basin, Northern Territory.
2(1)	JACOBSON, G.	Environmental and urban geology in Australia; notes on workshop meeting of government engineering geologists, November 1976.
2(1)	[1]MAFFI, C. SIMPSON, C.	Skylab photography for geological mapping.
2(1)	STEWART, A.J. WARREN, R.G.	The mineral potential of the Arunta Block, central Australia.
2(1)	BELFORD, D.J.	Quasicyclammina gen. nov. and Thalmannammina (Foraminiferida) from the Paleocene of Papua New Guinea.
2(1)	SIMPSON, C.J. DOUTCH, H.F.	The 1974 wet-season flooding of the southern Carpentaria Plains northwest Queensland.

2(1)	[5]TEDFORD, R.H. [5]ARCHER, M. [5]BARTHOLOMAI, A. PLANE, M. [5]PLEDGE, N.S. [5]RICH, T. [5]RICH, P. [4]WELLS, R.T.	The discovery of Miocene vertebrates, Lake Frome area, South Australia.
2(1)	[5]PIGRAM, C.J. JOHNSON, R.W. TAYLOR, G.A.M.	Investigation of hot gas emissions from Koranga volcano, Papua New Guinea.
2(1)	WELLS, A.T.	Magnesite-bearing calcrete near Gosses Bluff, Northern Territory.
2(1)	[4]FRAKES, L.A. EXON, N.F. [5]GRANATH, J.W.	Preliminary studies on the Cape Leeuwin manganese deposit off Western Australia.
2(1)	DAVIES, P.J. MARSHALL, J.F. FOULSTONE, D. [4]THOM, B.G. [4]HARVEY, N. [4]SHORT, A.D. [4]MARTIN, K.	Reef growth, southern Great Barrier Reef - preliminary results.
2(2)	[1]COOK, P.J. COLWELL, J.B. [2]FIRMAN, J.B. [2]LINDSAY, J.M. [4]SCHWEBEL, D.A. [4]VON DER BORCH, C.C.	The late Cainozoic sequence of southeast South Australia and Pleistocene sea-level changes.

2(2)	DRAPER, J.J.	Environment of deposition of the Carlo Sandstone, Georgina Basin, Queensland and Northern Territory.
2(2)	BLACK, L.P.	A Rb-Sr geochronological study in the Proterozoic Tennant Creek Block, central Australia.
2(2)	DERRICK, G.M.	Metasomatic history and origin of uranium mineralisation at Mary Kathleen, northwest Queensland.
2(2)	KENNEWELL, P.J. MATHUR, S.P. WILKES, P.G.	The Lander Trough, southern Wiso Basin, Northern Territory.
2(2)	BAIN, J.H.C.	Uranium mineralisation associated with late Palaeozoic acid magmatism in northeast Queensland.
2(3)	EWERS, G.R. SCOTT, P.A.	Geochemistry of the Cullen Granite, Northern Territory.
2(3)	KEMP, E.M. [4]BALME, B.E. [4]HELBY, R.J. [4]KYLE, R.A. [4]PLAYFORD, G. [5]PRICE, P.L.	Carboniferous and Permian palynostratigraphy in Australia and Antarctica - a review.
2(3)	NICOLL, R.S.	Conodont apparatuses in an Upper Devonian palaeoniscoid fish from the Canning Basin, Western Australia.

2(3)	GLIKSON, A.Y.	Evidence on the radius of the Precambrian Earth.
2(3)	[4]FRAKES, L.A. EXON, N.F. [5]GRANATH, J.W.	Chemistry of manganese nodules from the Cape Leeuwin field off Western Australia.
2(3)	BURNE, R.V.	Submarine fans and their hydrocarbon potential (Abstract).
2(3)	DAVIES, P.J. MARSHALL, J.F.	Factors affecting reef formations, southern Great Barrier Reef (Abstract).
2(3)	DERRICK, G.M.	Proterozoic patterns of sedimentation north and northeast of Mount Isa (Abstract).
2(3)	[3]DONNELLY, T.D. FERGUSON, JOHN KNUTSON, J. [3]LAMBERT, I.B. ROBERTS, W.M.B.	Investigations of the copper-bearing breccia pipes at Redbank, Northern Territory. (Abstract)
2(3)	FERGUSON, JOHN	Predicting the existence of diamonds in kimberlites from their inclusions. (Abstract)
2(3)	LANGWORTHY, A.	The Mordor Complex, Northern Territory. (Abstract)
2(3)	SEIDEL, G.E.	Playing with the 'GABHYD' hydraulic model of the Great Artesian Basin. (Abstract)

*2(4)	SENIOR, B.R. McCOLL, D.H. [5]LONG, B.E. [1]WHITELEY, R.J.	Geology and magnetic characteristics of precious opal deposits, southwest Queensland.
*2(4)	CARTER, E.K.	Geological maps in What maps are needed now? (Paper reporting on session of that name held at 6th BMR Symposium May '77. Other authors: D. Denham, G.A. Young, B.C. Barlow & R. Whitworth).
*2(4)	BURNE, R.V. [4]KANSTLER, A.J.	Geothermal constraints on the hydrocarbon potential of the Canning Basin, Western Australia.
*2(4)	JAQUES, A.L. ROBINSON, G.P.	The continent/island-arc collision in northern Papua New Guinea.
*2(4)	BULTITUDE, R.J. GARDNER, C.M. [2]NOON, T.A.	A recently discovered unconformity near the base of the Proterozoic Cloncurry Complex south of Mount Isa, northwestern Queensland.
*2(4)	BURNE, R.V. [2]CROWE, R.W.A.	Aeolianites in the Jurassic Jurgurra Sandstone, Canning Basin, Western Australia.
*3(1)	ROBINSON, G.P. [5]RATMAN, N.	Geology and tectonic development of the Manokwari area, Irian Jaya.

WITH EDITOR

BLAKE, D.H.	The Proterozoic and Palaeozoic rocks of The Granites-Tanami region, Western Australia and Northern Territory, and interregional correlations.
BURGER, D. SENIOR, B.R.	A stratigraphic and palynological re-interpretation of the north-eastern Eromanga Basin, Queensland, and a revision of the Ronlow Beds.
JOHNSON, R.W. [1,4]SMITH, I.E.M. [4]TAYLOR, S.R.	Hot-spot volcanism in St Andrew Strait, Papua New Guinea: geochemistry of a Quaternary bimodal rock suite.
[5]MOONEY, J.R. [3]BUBELA, B. FERGUSON, J. [4]HALLBERG, R.O.	Mathematical treatment of an experimental system simulating metal chelating in a reducing sedimentary environment.
[4]PEAT, C.J. MUIR, M.D. PLUMB, K.A. [1]McKIRDY, D.M. [1]NORVICK, M.S.	Proterozoic microfossils from the Roper Group, Northern Territory, Australia
[2]PREISS, W.V. WALTER, M.R. [2]COATS, R.P. WELLS, A.T.	Correlations of Adelaidean glaciogenic rocks in the Amadeus, Ngalia, and Georgina Basins.

OUTSIDE PUBLICATIONS

PUBLISHED OR IN PRESS*

BAIN, J.H.C. [2]BAKER, E.M. [2]WITHNALL, I.W.	Summary of results of investigations at the Jubilee Plunger gold deposit near Forsayth, North Queensland.	Queensland Government Mining Journal 78(905)
BLAKE, D.H. [5]LE CHEMINANT, A.N.	Paleohelikian alkaline volcanic rocks of the Dubawnt Group, District of Keewatin, Northwest Territories.	Geological Society of Canada 30th Annual Meeting, Abstracts 8, 1977.
BLAKE, D.H. [5]MILLER, A. [5]SCHAU, M.	Potassic volcanic rocks of the Paleohelikian Dubawnt Group and associated Cu, U, and Se mineralisation, Christopher Island region, District of Keewatin, NWT.	Geological Society of Canada 30th Annual Meeting, Abstracts 8 1977.
*[5]BROWN, C.M. PIGRAM, C. SKWARKO, S.K.	Mesozoic geology of Papua New Guinea	Palaeogeography Palaeoclimatology/Palaeoecology.
[3]BUBELA, B.	Microbiological production of utilisable energy from photosynthetically formed materials.	International Solar Energy Soc. Symposium: Practical Applications of Photosynthesis. University of NSW Sydney 1977.
[3]BUBELA, B.	Production of energy from waste.	Proceeding: Symposium, Australian Society for Microbiology p. 33, Melbourne 1977.

* BURGER, D.	Observations on the earliest angiosperm development, with special reference to Australia.	Proceedings IV International Palynology Conference, Lucknow.
BURGER, D.	Palynomorphs from Eromanga Basin formations in QDM Aramac 1 well.	Queensland Government Mining Journal, 78 (909), 331-336.
[4]CAWTHORN, R.G. [4]McIVER, J.R. [4]McCARTHY, T.S. [5]WYATT, B.A. FERGUSON, JOHN [5]BARNES, S.J.	Liquid immiscibility in high-magnesia basalts from the Ventersdorp Supergroup, South Africa.	Encyclopedia on Volcanoes and Volcanology (Ed. J. Green). Dowden, Hutchinson, and Ross, Stroudsberg, Pennsylvania.
[5]CIFELLI, R. BELFORD, D.J.	The types of several species of Tertiary planktonic foraminifera in the collections of the US National Museum of Natural History.	Journal of Foraminiferal Research, 7(2), 101-105.
*[5]COOKE, R.J.S. JOHNSON, R.W.	Papua New Guinea.	in: Encyclopedia of Volcanoes and Volcanology (Ed. J. Green). Dowden, Hutchinson, and Ross, Stroudsberg, Pennsylvania.
*[4]COOPER, R.A. [4]JAGO, J.B. [4]MACKINNON, D.I. SHERGOLD, J.H. [4]VIDAL, G.	Late Precambrian and Cambrian fossils from northern Victoria Land and their stratigraphic implications.	Proceedings SCAR Symposium Wisconsin Ausgust 1977.
CRICK, I.H.	Geochemical forecasts of volcanic eruptions in Papua New Guinea.	Bulletin Volcanologique, 39, 156.

*[2]CROWE, R.W.A. TOWNER, R.R.	Definitions of new and revised rock units in the Canning Basin.	Geological Survey of Western Australia Annual Report.
* DAVIES, P.J. [3]BUBELA, B. FERGUSON, JAMES	The formation of ooids.	Sedimentology
DAVIES, P.J. [3]BUBELA, B. FERGUSON, J.	Simulation of carbonate diagenetic processes: formation of dolomite, huntite and monohydrocalcite by reactions between nesquehonite and brine.	Chemical Geology 19, 187-214, 1977.
* DAVIES, P.J. [4]HOPLEY, D.	Coral Reef Symposium - Atlantic Meets Pacific.	SEARCH
DAVIES, P.J. [4]KINSEY, D.W.	Holocene reef growth - One Tree Island, Great Barrier Reef.	Marine Geology 24, 1-11, 1977.
* DAVIES, P.J. MARSHALL, J.F. [4]THOM, B.G. [4]HARVEY, N. [4]SHORT, A.D. [4]MARTIN, K.	Reef development - Great Barrier Reef.	Proceedings of the Third International Symposium on Coral Reefs, Miami, Florida
DERRICK, G.M. [2]WILSON, I.H. HILL, R.M.	Revision of Stratigraphic Nomenclature in the Precambrian of northwestern Queensland: III Mount Isa Group.	Queensland Government Mining Journal, 77, Oct. 1976.

DERRICK, G.M. [2]WILSON, I.H. HILL, R.M.	Revision of stratigraphic nomenclature in the Precambrian of northwestern Queensland: VI Mary Kathleen Group.	Queensland Government Mining Journal, 78, 15-23, 1977.
DERRICK, G.M. [2]WILSON, I.H. HILL, R.M.	Revision of stratigraphic nomenclature in the Precambrian of northwestern Queensland: VII Mount Albert Group.	Queensland Government Mining Journal, 78, 113-116, 1977.
DERRICK, G.M. [2]WILSON, I.H. HILL, R.M.	Revision of stratigraphic nomenclature in the Precambrian of northwestern Queensland: IV Malbon Group.	Queensland Government Mining Journal, 77, October 1976.
DERRICK, G.M. [2]WILSON, I.H. HILL, R.M.	Revision of stratigraphic nomenclature in the Precambrian of northwestern Queensland: V Soldiers Cap Group.	Queensland Government Mining Journal, 77, October 1976.
* DICKINS, J.M.	Climate of the Permian in Australia the invertebrate faunas.	Palaeogeography Palaeoclimatology Palaeoecology.
* DICKINS, J.M.	Permian Gondwana climate.	Chayanica Geologica.
DICKINS, J.M. [5]SHAH, S.C.	Correlation of the Permian marine sequence in India and Western Australia.	4th International Gondwana Symposium, Key paper.

* DICKINS, J.M. TOWNER, R.R. [2]CROWE, R.W.A.	Permian cold water marine fauna in the Grant Formation of the Canning Basin, Western Australia.	Palaeontological Journal of India.
*[3]DONNELLY, T.H. [3]LAMBERT, I.B. [3]OEHLER, D.Z. [4]HALLBERG, J.A. [5]HUDSON, D.R. [5]SMITH, J.W. [5]BAVINGTON, O.A. [4]GOLDRING, L.	A reconnaissance study of stable isotope ratios in Archaean rocks from Yilgarn Block, Western Australia.	Journal of Geological Society of Australia.
[5]DUBOIS, J. [5]LAUNAY, J. [5]RECY, J. MARSHALL, J.	New Hebrides Trench: Subduction rate from associated lithospheric bulge.	Canadian Journal of Earth Sciences, 14, 250-255, 1977.
[5]EADE, K.E. BLAKE, D.H.	Geology of the Tulemalu map-area, District of Keewatin.	Geological Survey of Canada Paper 77-1A, 209-211, 1977.
EWERS, G.R.	Experimental hot water - rock interactions and their significance to natural hydrothermal systems in New Zealand.	Geochimica et Cosmochimica Acta 41, 143-150, 1977
EWERS, G.R. [4]KEAYS, R.R.	Volatile and precious metal zoning in the Broadlands geothermal field, New Zealand.	Economic Geology 72, 7, 1977.
* FERGUSON, JAMES [3]BUBELA, B. DAVIES, P.J.	Synthesis and possible mechanism of formation of radial carbonate ooids.	Chemical Geology.

FERGUSON, JOHN ELLIS, D.J. [1]ENGLAND, R.N.	Unique spinel-garnet lherzolite inclusion in kimberlite from Australia.	Geology 5, 278-280 1977
FERGUSON, JOHN SHERATON, J.W.	Petrogenesis of kimberlitic rocks and associated xenoliths of southeastern Australia.	Extended Abstracts - 2nd International Kimberlite Conference, Santa Fe, 1977.
[4]FORD, J.H. [4]GREEN, D.C. [5]HULSTON, J.R. CRICK, I.H. [4]SHEPPARD, S.M.F.	Stable isotope studies on Bougainville and in Matupi Harbour, New Britain, Papua New Guinea.	Volcanic processes in ore genesis, Geological Society of London, Special Publication 7.
[4]FREY, F.A. FERGUSON, JOHN [4]CHAPPELL, B.W.	Petrogenesis of South African and Australian kimberlitic suites.	Extended abstracts - 2nd International Kimberlite Conference, Santa Fe, 1977.
*[4]FRIPP, R.E.P. [3]DONNELLY, T.H. [3]LAMBERT, I.B.	Sulphur isotope results for Archaean banded iron-formation, Rhodesia.	In "Metallogenesis 76: A symposium on mineral deposits and the transport and deposition of metals", Geological Society of South Africa.
*[5]GALLOWAY, R.W. KEMP, E.M.	Late Cainozoic environments in Australia.	Ecological Biogeography in Australia (A. Keast, Ed.). W. Junk, The Hague.
*[4]GLAESSNER, M.F. WALTER, M.R.	Australian Precambrian palaeobiology.	Precambrian Geology of the Southern Hemisphere, D.R. Hunter (Ed.), Elsevier.
GLIKSON, A.Y.	Trace element geochemistry and origin of early Precambrian acid igneous series, Barberton Mountains.	Geochimica et Cosmochimica Acta 40, 10, 1261-1280.

GLIKSON, A.Y.	On the origin of early Archaean gneisses.	Contributions to Mineralogy and Petrology, 62, 171-178, 1977.
GLIKSON, A.Y.	Vestiges of a beginning.	Geology, 5, 68-71, 1977.
* GLIKSON, A.Y.	On the basement of Canadian greenstone belts.	Canadian Geoscience.
* GLIKSON, A.Y.	Precambrian sial-sima distribution patterns: evidence for Earth expansion.	Tectonophysics.
* GORTER, J.D. NICOLL, R.S.	Reptilian fossils from Windjana Gorge, Western Australia.	Journal of the Royal Society of Western Australia.
[4]HALLBERG, R.O. [3]BUBELA, B. FERGUSON, J.	Simulation in two reducing systems.	Limnology & Oceanography.
* IDNURM, M. SENIOR, B.R.	Palaeomagnetic ages of weathered profiles in the Eromanga Basin, Queensland.	Palaeogeography Palaeoclimatology Palaeoecology.
JACOBSON, G.	Tanjung Karang water supplies, Indonesia.	Chapter 5 - Groundwater Studies in Report on Australian Aid Mission, 1977. Australian Development Assistance Bureau.
JACOBSON, G.	The contribution of geology towards management of the environment.	Bulletin of the International Association of Engineering Geology 14, 4, 1976.

JACOBSON, G. [5]BOURKE, R.M.	Observations of karst hydrology in Waga Valley, Papua New Guinea.	Helictite, 13, 3-18, 1975.
* JOHNSON, R.W. JAQUES, A.L.	Continent-arc collision and reversal of arc polarity: new interpretations from a critical area.	Tectonophysics
* JOHNSON, R.W. MACKENZIE, D.E. [1,4]SMITH, I.E.M.	Volcanic rock associations at convergent plate boundaries: reappraisal of the concept using case histories from Papua New Guinea.	Bulletin of Geological Society of America.
* JONES, H.A. DAVIES, P.J.	Preliminary studies of offshore placer deposits - eastern Australia.	Contributions to Sedimentology.
* KEMP, E.M.	The palynology of the Permo-Carboniferous in Tasmania.	Geological Survey of Tasmania - Bulletin 56
* KEMP, E.M.	Tertiary climatic evolution and vegetation history in the southeast Indian Ocean region.	Palaeogeography, Palaeoclimatology, Palaeoecology.
KEMP, E.M. [2]HARRIS, W.K.	The palynology of Early Tertiary sediments, Ninety-east Ridge, Indian Ocean.	Special Papers in Palaeontology 14, 1-70. 1977. (The Palaeontological Association, London).
[4]KING, G.M. [3]SKYRING, G.W.	A seasonal study of methanogenesis in a Georgia salt marsh.	Proceedings American Society of Microbiology, Number 243 1977.

[3]LAMBERT, I.B.	Notes on exploration guides for stratiform lead-zinc ores, geochemical and geobiological evolution in the Precambrian, and massive sulphide deposits of the Noranda area.	Technical Connumication, 61, CSIRO, Mineral Research Laboratories.
[3]LAMBERT, I.B.	The genesis of low-temperature hydrothermal base metal deposits.	In Glover, J.E. and Groves, D.I. Eds 1977. "Recent Geological Research Relating Low-Temperature Aqueous Geochemistry to weathering, Ore Genesis and Exploration. University of Western Australia, 3-13.
[5]LE CHEMINANT, A.N. BLAKE, D.H. [5]LEATHERBARROW, R.W. [5]DE BIE, L.	Geological Studies: Thirty Mile Lake and MacQuoid Lake Map-areas, District of Keewatin.	Geological Survey of Canada, Paper 77-1A, 205-208, 1977.
LIMER EXPEDITION TEAM 1975 (18 participants)	Metabolic processes of coral reef communities at Lizard Island, Queensland.	SEARCH 7, 11-12, 1976.
[4]McIVER, J.R. FERGUSON, JOHN	Kimberlitic melilititic trachytic and carbonatitic eruptives at Saltpetre Kop, Sutherland, South Africa.	Extended abstracts - 2nd International Kimberlite Conference, Santa Fe, 1977.
[1]MAFFI, C.E.	High altitude multiband photography of Landsat-1 Mount Isa test area. An assessment of its value to geological mapping.	Bulletin of the Remote Sensing Association of Australia, 3(1) 20-26.

* MARSHALL, J.F. DAVIES, P.J.	Skeletal carbonate variation on the continental shelf of eastern Australia.	Sedimentology.
* MARSHALL, J.F. [5]LAUNAY, J	Uplift rates of the Loyalty Islands as determined by $^{230}Th/^{234}U$ dating of raised coral terraces.	Quaternary Research.
[5]MILES, R.S. YOUNG, G.C.	Placoderm interrelationships reconsidered in the light of new ptyctodontids from Gogo, Western Australia.	In: S.M. Andrews, R.S. Miles, A.D. Walker (Eds) - "Problems in Vertebrate Evolution" Linnean Society Symposium Series, 4: 123-98, London Academic Press.
NICOLL, R.S.	The effect of Late Carboniferous/Early Permian glaciation on the distribution of conodonts in Australia.	The Geological Association of Canada, Special Paper 15, 274-278.
[2]NOON, T.A.	Mineral exploration surveys in the Duchess 1:250 000 Sheet area, northwest Queensland.	Queensland Government Mining Journal, 77, 351-358, 1976.
[4]OSHRAIN, R.L. [3]SKYRING, G.W.	Sulfide production in salt marsh soils.	Proceedings American Society of Microbiology, Bacterial Proceedings 241, 1977.
OVERSBY, B.S. PALFREYMAN, W.D. BLACK, L.P. [1]COOPER, J.A. BAIN, J.H.C.	Georgetown, Yambo and Coen Inliers - regional geology.	In: C.L. Knight (Editor) Economic Geology of Australia and Papua New Guinea, 1. Metals Australian Institute of Mining and Metallurgy Monograph 5: 511-516.

OVERSBY, B.S. [2]WITHNALL, I.W. [2]BAKER, E.M.	Revision of pre-Mesozoic geology in Woolgar River, Stawell River, and Glen Loth areas, Gilberton 1:250 000 Sheet area, north Queensland.	Queensland Government Mining Journal, 77, October 1976.
PAGE, R.W.	Response of U-Pb zircon system to low-grade regional metamorphism in Proterozoic igneous rocks, Mount Isa, Australia.	Carnegie Institute of Washington Year Book 75, 813-821, December 1976.
PAGE, R.W. RYBURN, R.J.	K-Ar ages and geological relations of intrusive rocks in New Britain.	Pacific Geology 12, 99-105, 1977.
PERRY, W.J. CRICK, I.H.	Aerial thermal infrared survey, Rabaul, Papua New Guinea, 1973.	In: Volcanism in Australasia R.W. Johnson (Ed.).
[5]PETERSEN, M.D. [3]LAMBERT, I.B. [5]AYRES, D.E.	Results of analysis of country rocks around the Woodlawn copper-lead-zinc orebody, southeastern New South Wales.	Technical Communication 63, CSIRO, Minerals Research Laboratories.
[4]RICHARDS, J.R. PAGE, R.W. BLACK, L.P.	Age and isotopic studies in economic geology.	In: C.L. Knight (Editor), Economic Geology of Australia and Papua New Guinea, 1. Metals. Australasian Institute of Mining and Metallurgy Monograph 5: 15-25.
*[5]RITCHIE, A. GILBERT-TOM- LINSON, J.	Ordovician vertebrates from the Northern Territory of Australia.	Alcheringa

RYBURN, R.J. [4]RAHEIM, A. [4]GREEN, D.H.	Determination of the P, T paths of natural eclogites during metamorphism - record of subduction.	Lithos, 9, 161-164, 1976.
* SENIOR, B.R.	Silcrete and chemically weathered sediments in southwest Queensland.	In: Australian Silcretes, T. Langford-Smith (Ed.).
* SHERATON, J.W.	Origin of charnockitic rocks of MacRobertson Land.	Third symposium on Antarctic geology and geophysics.
SHERGOLD, J.H.	Classification of the trilobite Pseudagnostus.	Palaeontology, 20(1): 69-100.
SIMPSON, C.J.	The use of colour aerial photography for geological mapping by the Bureau of Mineral Resources, Australia.	Bulletin of the Remote Sensing Association of Australia, 3(2), 89-97
[3]SKYRING, G.W. [3]CHAMBERS, L.A.	Biological sulfate reduction in carbonate sediments of a coral reef.	Australian Journal of Marine and Freshwater Research 27, 595-602, 1976.
[3]SKYRING, G.W. [3]JONES, H.E.	Variations in the spectrum of desulfoviridin from Desulfovibrio gigas	Australian Journal of Biological Sciences,29, 291-299, 1976.
[3]SKYRING, G.W. [3]JONES, H.E.	Dithionite reductions in the presence of tetrapyrnole - containing fraction from the desulfoviridin of Desulfovibrio gigas.	Australian Journal of Biological Sciences, 30, 1-11, 1977.

*[3]SKYRING, G.W. [3]JONES, H.E. [4]GOODCHILD, D.	The taxonomy of some new isolates of dissimilatory sulfate-reducing bacteria.	Canadian Journal of Microbiology, 1977.
[5]STRACKE, K.J. FERGUSON, JOHN BLACK, L.P.	Structural setting of kimberlites in southeastern Australia.	Extended Abstracts - 2nd International Kimberlite Conference, Santa Fe, 1977.
* TINGEY, R.J.	The geology and geological evolution of the Prince Charles Mountains, Antarctica.	Third Symposium on Antarctic Geology and Geophysics.
[3]TRUDINGER, P.A.	Microbiological processes in relation to ore genesis.	In. Handbook of Stratabound and Stratiform Ore Deposits. Ed. K.H. Wolf, Chapter 6 1976.
[2]VAN DE GRAAFF, W.J.E. [2]CROWE, R.W.A. [2]BUNTING, J.A. JACKSON, M.J.	Relict Early Cainozoic drainages in arid Western Australia.	Zeitschrift fur Geomorphologie 21(4), 379-400.
WALTER, M.R.	Interpreting stromatolites.	American Scientist 65, 563-571, 1977.
WALTER, M.R. (Editor)	Life in the Precambrian.	Special Issue (IGC) of Precambrian Research, 5, 105-219.
WALTER, M.R.	Preface to "Life in the Precambrian".	Precambrian Research, 5, 105-107.
[2]WILSON, I.H.	Mineral exploration under Authorities to Prospect in the Mount Isa 1:250 000 Sheet area, northwestern Queensland.	Queensland Government Mining Journal 78, 222-233, 1977.

WYBORN, D.,	Discussion - the Jindabyne thrust and its tectonic, physiographic and petrogenetic significance.	Journal of Geological Society of Australia, 24(4), 233-236.
* YOUNG, G.C.	A new Early Devonian petalichthyid fish from the Taemas/ Wee Jasper region of New South Wales.	Alcheringa.

SUBMITTED OR IN PREPARATION

*[5]ADAMS, C.G. BELFORD, D.J.	Reticulogyra gen. nov. (Foraminiferida) from the Chimbu Limestone, Papua New Guinea.	
[4]ARCULUS, R.J. JOHNSON, R.W.	Criticism of generalised models for the magmatic evolution of arc-trench systems.	Earth and Planetary Science Letters.
[4]ARCULUS, R.J. JOHNSON, R.W.	Evaluation of generalised models for the magmatic evolution of arc-trench systems (abstract only).	
[4]ARCULUS, R.J. JOHNSON, R.W. [4]PERFIT, M.R.	Alkaline volcanic rocks from the Tabar-to-Feni Islands, Papua New Guinea: Oceanic or island-arc magmas? (abstract only).	
BLACK, L.P. [4]BELL, T.H. [4]RUBENACH, M.J. [2]WITHNALL, I.W.	Geochronology of discrete structural-metamorphic events in a multiply deformed Precambrian terrain.	
[3]BUBELA, B. FERGUSON, JAMES	Effect of extractory methods on the composition of organic matter isolated from sediments.	
[3]BUBELA, B. [3]JOHNS, I.A. FERGUSON, JAMES	A system for simulation of evaporative sedimentary environments.	Limnology and Oceanography.

* BULTITUDE, R.J.	Bogana volcano, Bougainville Island, Papua New Guinea: geology, petrology, and summary of eruptive history between 1882 and 1975.	Geological Survey Papua New Guinea Memoir.
* BURGER, D.	Late Jurassic and Early Cretaceous palynomorphs from GSQ Tambo 2, eastern Eromanga Basin, Queensland.	Queensland Government Mining Journal.
CHAPRONIERE, G.C.H.	A record of 'Lepidocyclina' from DSDP Leg 30, Site 286, Western Pacific Ocean.	Journal of Paleontology.
* DERRICK, G.M. [2]WILSON, I.H. HILL, R.M.	Revision of stratigraphic nomenclature in the Precambrian of northwestern Queensland: VIII igneous rocks.	Queensland Government Mining Journal.
[4]EDWARDS, A.C. [4]LOVERING, J.F. FERGUSON, JOHN	High pressure basic inclusions from the Kayrunnera kimberlitic pipe in New South Wales.	Contributions to Mineralogy and Petrology.
GLIKSON, A.Y.	Early Precambrian tonalite-granodiorite suites.	In: Trondhjemites, Dacites and Related Rocks (ed. F. Barker).
[4]HALLBERG, J.A. GLIKSON, A.Y.	Archaean granite-greenstone terrains of Western Australia.	In: Precambrian of the Southern Continents (ed. D.R. Hunter).
JOHNSON, R.W. [4]ARCULUS, R.J.	Volcanic rocks from the Witu Islands, Papua New Guinea: their chemical characteristics, origin, and tectonic significance (abstract only).	

JOHNSON, R.W. MACKENZIE, D.E. [1,4]SMITH, I.E.M.	Delayed partial melting of subduction-modified mantle in Papua New Guinea.	Tectonophysics.
KNUTSON, JANICE FERGUSON, JOHN ROBERTS, W.M.B. [3]DONNELLY, T.H. [3]LAMBERT, I.B.	Petrogenesis of the copper-bearing breccia pipes - Redbank, Northern Territory Australia.	Economic Geology.
LAMBERT, I.B.	Massive copper-lead-zinc deposits in felsic volcanic sequences of Australia and Japan: a comparative review.	
LANGWORTHY, A.P. BLACK, L.P.	The Mordor Complex - a highly differentiated potassic intrusion with kimberlitic affinities in central Australia.	Contributions to Mineralogy and Petrology.
NEEDHAM, R.S.	Giant-scale hydroplastic deformation, structures between sandstone and basalt, Northern Territory, Australia.	Sedimentology.
PAGE, R.W.	Response of U-Pb zircon and Rb-Sr total rock and mineral systems to low-grade regional metamorphism in Proterozoic igneous rocks, Mount Isa, Australia.	
[1]REYNOLDS, M.A. [1]BEST, J.G. JOHNSON, R.W.	Rhyolitic volcanic activity in a marginal basin: the 1953-57 eruption of Tuluman volcano, Papua New Guinea.	Geological Survey Papua New Guinea Memoir.

[4]PETERSEN, M.D. [3]LAMBERT, I.B.	Implications of petrographic, mineralogical and geochemical investigations of rocks around Woodlawn copper-lead-zinc orebody, southeastern New South Wales.	Technical Communication, 61 CSIRO, Minerals Research Laboratories.
SHERATON, J.W.	Potassium-rich basaltic rocks from Antarctica.	
SHERGOLD, J.H. DRUCE, E.C.	Georgina Basin.	In Lower Palaeozoic Rocks of the World, 3. Australia (Ed. C.H. Holland).
STEWART, A.J.	A barred-basin marine evaporite in the Upper Proterozoic of the Amadeus Basin, central Australia.	
[2]WILSON, I.H.	Possible Andean-type volcanics in the Proterozoic of north-western Queensland.	Precambrian Research.

EXPLANATORY NOTES AND MAPS

PUBLISHED OR IN PRESS*

5373	Field Island 1:100 000 Preliminary	NEEDHAM, R.S. [1]SMART, P.G. [1]WATCHMAN, A.L.
5472	Cahill 1:100 000 Preliminary	NEEDHAM, R.S. [1]SMART, P.G. [1]WATCHMAN, A.L.
5571	Gilruth 1:100 000 Preliminary	NEEDHAM, R.S. [1]SMART, P.G. [1]WATCHMAN, A.L.
SB/55-6	Madang	ROBINSON, G.P. JAQUES, A.L. BROWN, C.M.
SB55/8 and 12	Cape Raoult-Arawe	RYBURN, R.J.
SB55/10	Markham	TINGEY, R.J. [1]GRAINGER, D.J.
* SC55-6 SC55-7 SC55-11	Port Moresby-Kalo-Aroa	PIETERS, P.E.
* SE/51-16	Crossland	TOWNER, R.R.
* SE52-12	Winnecke Creek	HULEATT, M.B.
SE52-14	Billiluna	BLAKE, D.H. PASSMORE, V.L. [2]MUHLING, P.C.

	SE52-15	Tanami	HODGSON, I.M.
*	SE52-16	Tanami East	HULEATT, M.B.
*	SE53-9	South Lake Woods	KENNEWELL, P.J.
	SE54-8	Red River	SMART, J. BAIN, J.H.C.
	SF51-4	Dummer	WYBORN, LESLEY A.I.
*	SF52-1	Cornish	[2]CROWE, R.W.A.
*	SF52-2	Lucas	[2]CROWE, R.W.A. [2]MUHLING, P.C.
	SF52-3	The Granites	HODGSON, I.M.
*	SF52-4	Mount Solitaire	OFFE, L.A. KENNEWELL, P.J.
	SF52-5	Helena	YEATES, A.N.
	SF52-6	Stansmore	BLAKE, D.H. YEATES, A.N.
*	SF52-7	Highland Rocks	HODGSON, I.M.
	SF52-8	Mount Theo	STEWART, A.J.
	SF52-10	Webb	BLAKE, D.H.
*	SF53-5	Mount Peake	OFFE, L.A.
*	SF53-14	Tennant Creek	DODSON, R.G. GARDENER, J.E.F.
	SG51-12	Yowalga	KENNEWELL, P.J.

SG51-16	Westwood	KENNEWELL, P.J.
* SG52-13	Lennis	JACKSON, M.J.
* SG52-14	Waigen	JACKSON, M.J.
SH51-1	Cundeelee	[2]BUNTING, J.A. [2]VAN DE GRAAFF, W.J.E.
SH51-7	Minigwal	[2]BUNTING, J.A. [2]BOEGLI, J.C.
SH51-8	Plumridge	[2]VAN DE GRAAFF, W.J.E. [2]BUNTING, J.A.
SH52-1	Vernón	[2]VAN DE GRAAFF, W.J.E.
SH52-2	Wanna	KENNEWELL, P.J.

WITH EDITORS

SA54-11 SA54-15	Aitape Vanimo	[1]HUTCHISON, D.S.
SA54-16	Wewak	[1]HUTCHISON, D.S.
SA55-13	Sepik	[1]HUTCHISON, D.S.
SB55-13	Kikori	PIETERS, P.E.
SE53-13	Green Swamp Well	KENNEWELL, P.J.
SE54-5	Westmoreland (2nd Edition)	[2]GRIMES, K.G. SWEET, I.P.

SF51-7	Sahara	YEATES, A.N. TOWNER, R.R.
SF51-8	Percival	YEATES, A.N.
SF51-11	Tabletop	YEATES, A.N. [2]CHIN, R.C.
SF51-12	Ural	TOWNER, R.R.
SF51-16	Morris	[2]CROWE, R.W.A.
SF52-9	Wilson	TOWNER, R.R.
SF52-13	Ryan	TOWNER, R.R.
SF53-1	Lander River	KENNEWELL, P.J. OFFE, L.A.
SG51-11	Robert	JACKSON, M.J.
SG51-15	Throssell	[2]BUNTING, J.A. JACKSON, M.J. [2]CHIN, R.J.
SH51-3	Rason	[2]GOWER, C.F. [2]BOEGLI, J.C.

SPECIAL MAPS

PUBLISHED OR IN PRESS*

1:500 000	Geology of the Victoria River region	SWEET, I.P.
1:500 000	Geology of the Kimberley region, Western Australia: West Kimberley	[1]GELLATLY, D.C. DOW, D.B. PLUMB, K.A. DERRICK, G.M.
1:500 000	Geology of the Kimberley Region, Western Australia: North Kimberley.	PLUMB, K.A. DOW, D.B.
* 1:100 000	Mount Isa	HILL, R.M. [2]WILSON, I.H.
1:500 000	Bathurst Island, Melville Island, and Coburg Peninsula.	HUGHES, R.J.
1:1 000 000	Geology of the northwestern part of the Eromanga Basin.	MOND, A.
1:1 000 000	Geology of the northern Eromanga Basin.	SENIOR, B.R. SWOBODA, R. MOND, A.

WITH EDITORS

1:100 000	Prospector	[2]WILSON, I.H. DERRICK, G.M. HILL, R.M.

1:1 000 000	Continental shelf sediments, central and southern NSW shelf.	DAVIES, P.J.
1:10 000 000	Major structural units (including sedimentary basins).	D'ADDARIO, G.W. PALFREYMAN, W.D. BULTITUDE, J.M.
1:10 000 000	Cainozoic cover and weathering showing thicknesses.	D'ADDARIO, G.W. PALFREYMAN, W.D. BULTITUDE, J.M.
1:10 000 000	Surface drainage and continental margin, Australia	D'ADDARIO, G.W. PALFREYMAN, W.D. MITCHELL, J. (with contributions by Geophysical Branch)
1:10 000 000	Main rock types, Australia.	D'ADDARIO, G.W. PALFREYMAN, W.D. BULTITUDE, J.M.

PRELIMINARY EDITION ISSUED

1:10 000	Coppins Crossing, Canberra	HENDERSON, G.A.M.
1:1 000 000	Geology of the Carpentaria and Karumba Basins (2 sheets).	SMART, J.
1:1 000 000	Geology of the Officer Basin, WA.	JACKSON, M.J.
1:1 000 000	Geomorphology of the Officer Basin, WA	JACKSON, M.J.

1:100 000 MAPS

PRELIMINARY EDITIONS ISSUED OR IN PREPARATION*

6757	Kennedy Gap	[2]WILSON, I.H. HILL, R.M.
6957	Quamby	[2]WILSON, I.H.
7659	Gilberton	[2]WITHNALL, I.W. OVERSBY, B.S. BAIN, J.H.C. [2]BAKER, E.M.
7661	Georgetown	OVERSBY, B.S. [2]WITHNALL, I.W. BAIN, J.H.C.
8293 8294 8393 8394	Manus Island	JAQUES, A.L. ROBINSON, G.P.

RECORDS

ISSUED

1975/26	PAGE, R.W. BLAKE, D.H.	Geochronology and related aspects of Proterozoic acid volcanic rocks and associated granites in The Granites-Tanami region, northwestern Australia.
1975/79	STUART-SMITH, P.G. HONE, I.G.	Shallow stratigraphic drilling in the Cahill and Jim Jim 1:100 000 Sheet areas, Alligator Rivers Region, NT, 1974.
1975/100	SHAW, R.D. WARREN, R.G. SENIOR, B.R. YEATES, A.N.	Geology of the Alcoota 1:250 000 Sheet area.
1975/102	PAGE, R.W. MAHON, M.W.	Isotopic age relationships of Precambrian rocks in The Granites-Tanami region, Northern Territory and Western Australia.
1975/127	[1]DUFF, B.A.	Factors in the deposition and mineralisation of a black shale west of Mary Kathleen, Queensland.
1975/137	JACOBSON, G. [5]BOURKE, R.M.	Observations of karst hydrology in the Waga Valley, Southern Highlands District, Papua New Guinea.

1975/162	[1]HUTCHISON, D.S.	Basement geology of the North Sepik region, Papua New Guinea.
1975/164	ROSSITER, A.G.	An orientation geochemical survey in the Georgetown aream north Queensland.
1075/169	[5]UNGEMACH, P.	Great Artesian Basin groundwater project - Explanatory note on digital model package, Great Artesian Basin Simulation Model (GABSIM).
1975/175	HILL, R.M. [2]WILSON, I.H. DERRICK, G.M.	Geology of the Mount Isa 1:100 000 Sheet area, northwest Queensland.
1976/18	WHITE, M.E. YEATES, A.N.	Plant fossils from the northeastern part of the Canning Basin, Western Australia.
1976/19	GOLDSMITH, R.C.M.	Tuggeranong sewerage tunnel connection: geological investigation 1975.
1976/24	[2]CROWE, R.W.A. TOWNER, R.R.	Permian depositional history of the Noonkanbah 1:250 000 Sheet area, WA.
1976/29	DRAPER, J.J.	The Devonian rocks of the Toko Syncline, western Queensland.
1976/34	MITCHELL, J.E.	Precambrian geology of the Westmoreland region, northern Australia: Part II The Cliffdale Volcanics.

1976/3	PETTIFER, G. SMART, J. HORSFALL, C.L. McDOWELL, M.I. GIBSON, D.L.	Geophysical and geological groundwater investigations Cape York Peninsula, 1974.
1976/42	GARDINER, J.E.	Heavy-mineral deposits along the coasts of Victoria, Tasmania and South Australia.
1976/53	BENNETT, D.G. GOLDSMITH, R.C.M. POLAK, E.J.	Foundation investigations at Murrumbidgee Bridge Site No 3, ACT, 1975. Engineering geology and seismic refraction survey.
1976/57	DRAPER, J.J.	Progress report on Georgina Basin geochemistry - results of 1974 field season.
1976/62	ABELL, R.S.	A groundwater investigation on Norfolk Island.
1976/63	BAIN, J.H.C. OVERSBY, B.S. [2]WITHNALL, I.W. [2]BAKER, E.M.	Gilberton 1:100 000 Geological Sheet preliminary field compilation data sheet.
1976/64	JACOBSON, G.	Preliminary investigation of groundwater resources, Cocos (Keeling) Islands, Indian Ocean, 1975.
1976/69	[1]FURSTNER, J.M.M.	Googong pipeline investigation 1975-76: expected ground conditions for the excavation.

1976/71	BENNETT, D.G. JACOBSON, G.	Defence Force Academy site, Duntroon, ACT; investigation of subsurface conditions 1975.
1976/78	ABELL, R.S.	A bibliography of groundwater recharge in Australia.
1976/82	[1]MAYO, W. [1]LONG, K.A.	Documentation of BMR Geological Branch computer programs
1976/89	COLWELL, J.B.	Heavy minerals in the late Cainozoic sediments of south-eastern South Australia.
1976/95	TOWNER, R.R. [2]CROWE, R.W.A. YEATES, A.N.	Notes on the geology on the southern part of the Canning Basin.
1976/98	ROSSITER, A.G. ARMSTRONG, K.J.	Soil sampling at the Big Reef and Two Micks gold mines, Forsayth, north Queensland.
1976/101	CRICK, I.H.	Shallow stratigraphic drilling in the Burnside Granite area, Batchelor 1:100 000 Sheet, Northern Territory, 1975.
1976/106	GOLDSMITH, R.C.M.	Murrumbidgee Park Drive, Tuggeranong, ACT, geological investigation.
1977/4	[2]WILSON, I.H. DERRICK, G.M. HILL, R.M. [1]DUFF, B.A. [2]NOON, T.A. ELLIS, D.J.	Geology of the Prospector 1:100 000 Sheet area (6857), Queensland.

1977/33	PLUMB, K.A.	McArthur Basin Project.

WITH EDITORS

1977/16	PIETERS, P.E. WYBORN, D.	Geological work in Antarctica.
1977/15	HOHNEN, P.D. [1]HORSFALL, K.R. PETTIFER, G.R.	Geological and geophysical investigations for urban development, Gungahlin, ACT, 1975-76.
1977/18	GOLDSMITH, R.C.M. [1]BRISCOE, G.	Preliminary geological investigations of Tennent Dam Sites 2 and 3, Gudgenby River, ACT, 1975-76.
1977/19	KENNARD, J.M. DRAPER, J.J.	BMR stratigraphic drilling in the Burke River Structural Belt, southeast Georgina Basin, 1974.
1977/20	ROSSITER, A.G.	A preliminary geological investigation of the Una May uranium prospect, Seigal 1:100 000 Sheet area, Northern Territory.
1977/21	LANGWORTHY, A.P. BLACK, L.P.	The Mordor Complex, a highly differentiated potassic intrusion with kimberlitic affinities in central Australia.
1977/23	ROBINSON, G.P. [5]RATMAN, N.	Explanatory notes on the Manokwari 1:250 000 geological sheet Irian Jaya, Indonesia.

1977/24	[1]HUTCHISON, D.S.	Results of the 1976 orientation stream sediment geochemical survey in NE Kepald Burang (Birds head), Irian Jaya, Indonesia.
1977/34	GARDINER, J.E.	Heavy-mineral sands along the coast of Western Australia.

IN PREPARATION

[1]BRISCOE, G. BENNETT, D.G.	Geological and geophysical investigation of reservoir sites in Tuggeranong, ACT, 1976.
[1]BRISCOE, G. KELLETT, J.R.	Engineering geology of the Queanbeyan urban area, NSW.
[1]BRISCOE, G. KELLETT, J.R. JACOBSON, G.	Canberra-Queanbeyan interaction study; geological factors in development planning.
COLWELL, J.B.	Stratigraphic drilling of stranded beach ridges, central western Victoria, 1977.
GARDNER, C.M.	Precambrian geology of the Westmoreland region, northern Australia: Part III Nicholson Granite Complex and Murphy Metamorphics.
GOLDSMITH, R.C.M.	Stromlo-Higgins Bulk Supply Main, geological investigations 1975, and review since construction 1977.

GOLDSMITH, R.C.M. PETTIFER, G.R.	Dairy Flat ACT report of sand and gravel investigations 1974-1976.
HENDERSON, G.A.M.	The geology of the Gundaroo/ Westmead Park/Nanima area, NSW.
HENDERSON, G.A.M. JACOBSON, G. TAYLOR, F.J.	Geological and geophysical investigations of sites for major buildings, Canberra City, Parkes, and Campbell, ACT, 1974-5.
HOHNEN, P.D.	The control of groundwater seepage by pumping from a bore at Torres Street, Red Hill, ACT.
HUTCHISON, D.S. [1]NORVICK, M.S.	Geology of the North Sepik region, PNG.
KELLETT, J.R.	Topsoil investigation, H-423 Booth District, ACT.
[1]MENDUM, J.R. [1]TONKIN, P.	Geology of the Tennant Creek area, NT.
NEEDHAM, R.S.	BMR's role in mineral exploration within the Pine Creek Geosyncline, 1949-1977.
OVERSBY, B.S.	Catalogue of field compilation sheets of the Newcastle Range Volcanics and associated rocks in the Mount Surprise, Galloway, and northernmost Georgetown 1:100 000 Sheet areas.

PIETERS, P.E. RYBURN, R.J. TRAIL, D.S.	Geological work in the Birdshead, Irian Jaya, Indonesia, 1976.
PURCELL, D.C.	Tuggeranong Sewer Tunnel, ACT Engineering Geology Completion Report, 1977.
ROSSITER, A.G. SCOTT, P.A.	Stream sediment geochemistry of the Forsayth 1:100 000 Sheet area, Queensland.
SHERATON, J.W. OFFE, L.A.	Geological work in Antarctica, 1976
STUART-SMITH, P.G.	Shallow stratigraphic drilling in the Kapalga 1:100 000 Sheet area, Alligator Rivers region, NT, 1974-6.
VANDEN BROEK, P.H.	The urban and engineering geology of the proposed Darwin East Urban Development Area, NT.
VANDEN BROEK, P.H.	Geological investigations for airport sites Canberra and environs, 1976.
WARREN, R.G.	Geochemical sampling of the Edwards Creek prospect, Arunta Block, central Australia.

BMR TECHNICAL NOTES

March 1977	PURCELL, D.C. [5]FELL, R.	Suva water supply augmentation study. Report on storage dam investigations, 1976. Technical report to ADAA by BMR and Department of Construction.
March 1977	WILSON, E.G.	The contamination of groundwater in urban areas by hydrocarbons, with brief notes on the hydrogeology of Canberra City, ACT.
May 1977	JACOBSON, G.	Groundwater pollution by hydrocarbons, Center Cinima, Canberra City, ACT.
July 1977	GOLDSMITH, R.C.M.	Eastern Parkway Corridor Study. Geological appraisal of the route across Dairy Flat, ACT.
July 1977	PURCELL, D.C.	Stromlo-Higgins bulk supply main, Stromlo tunnel section. Engineering Geology Completion Report.
August 1977	JACOBSON, G. HOHNEN, P.D. EVANS, R.	Groundwater pollution by hydrocarbons in Canberra City, additional investigations, May-July 1977.
October 1977	JACOBSON, G. WILSON, E.G.	Movement of the groundwater pollution plume, Canberra City July-September, 1977, and glossary of hydrogeological terms.

R77/1000 Cat. No. 78 7209 0
ISBN 0 642 03565 2