DEPARTMENT OF
~~NATIONAL RESOURCES~~
NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1979/61

GEOLOGICAL BRANCH
SUMMARY OF ACTIVITIES
1979

Chief Geologist: J.N. Casey

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

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Record 1979/61

GEOLOGICAL BRANCH
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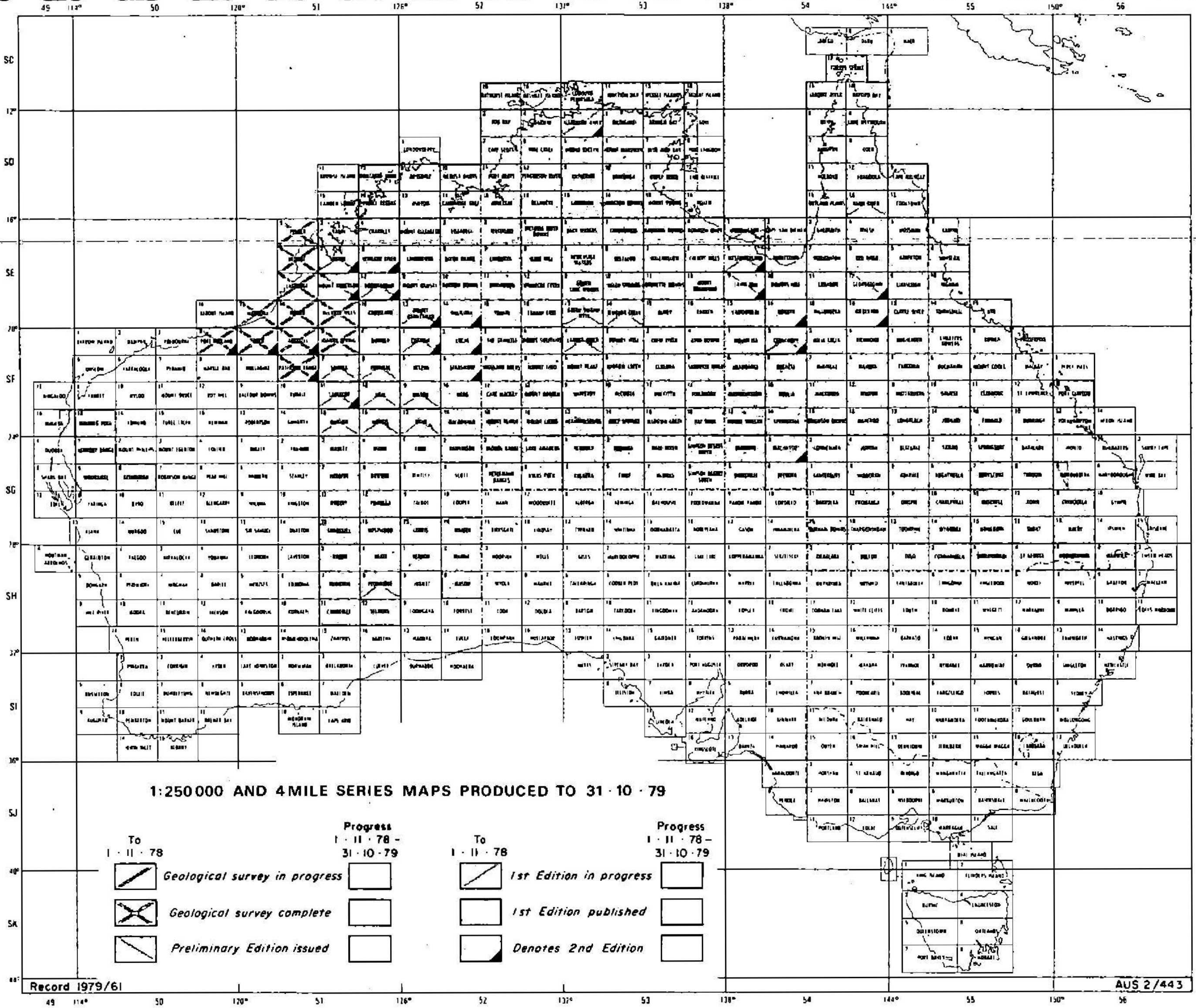


ANTARCTICA

1:250 000 SERIES MAPS

PRELIMINARY EDITION ISSUED – TO 31 · 10 · 77

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

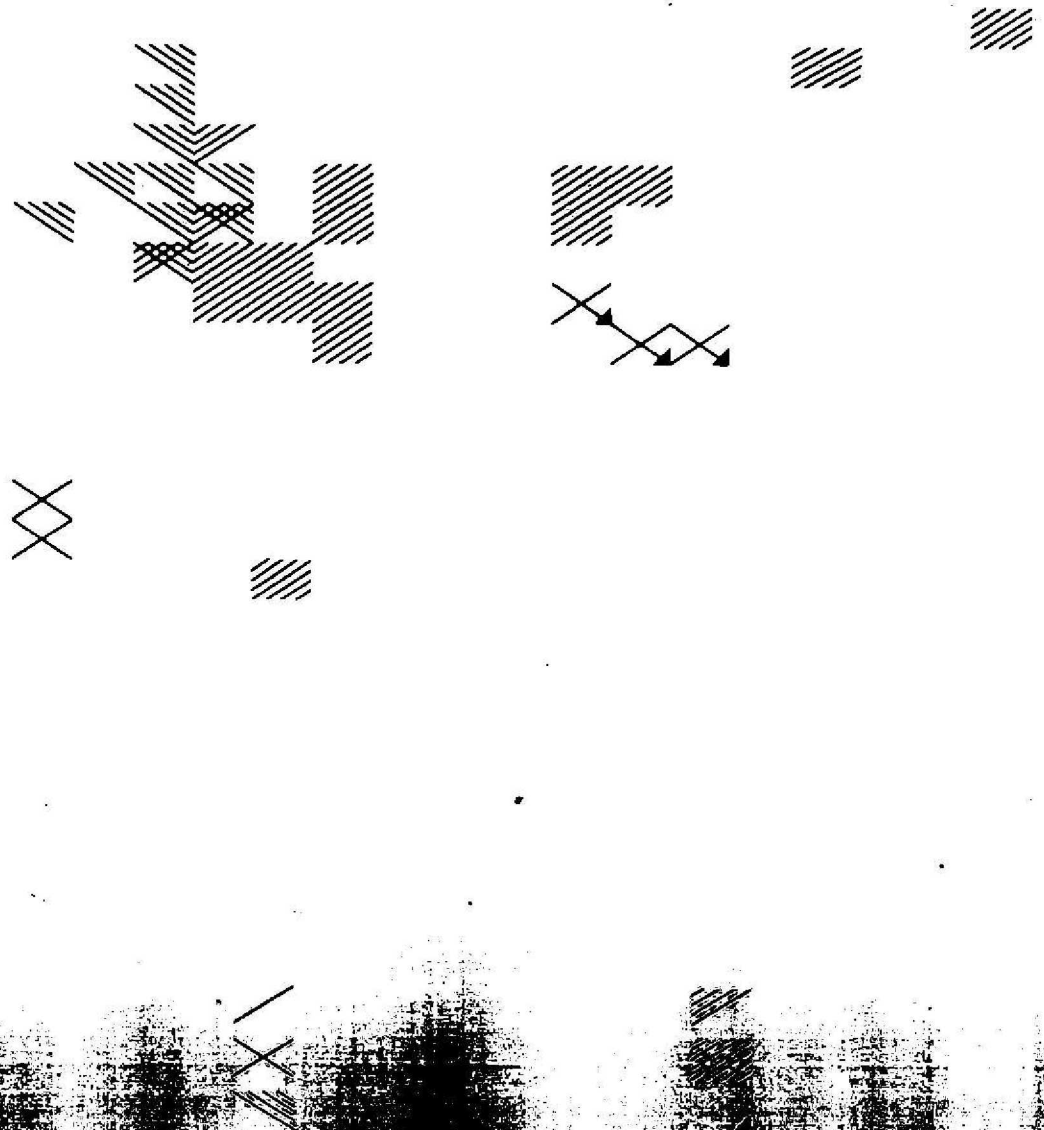
No maps were issued in period 1 · 11 · 77 to 31 · 10 · 79

ENDERBY LAND FIELD STUDIES

Geological mapping · Summer 76/77

Geochronological and structural studies · Summer 77/78

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



SEE UNDERSHEET

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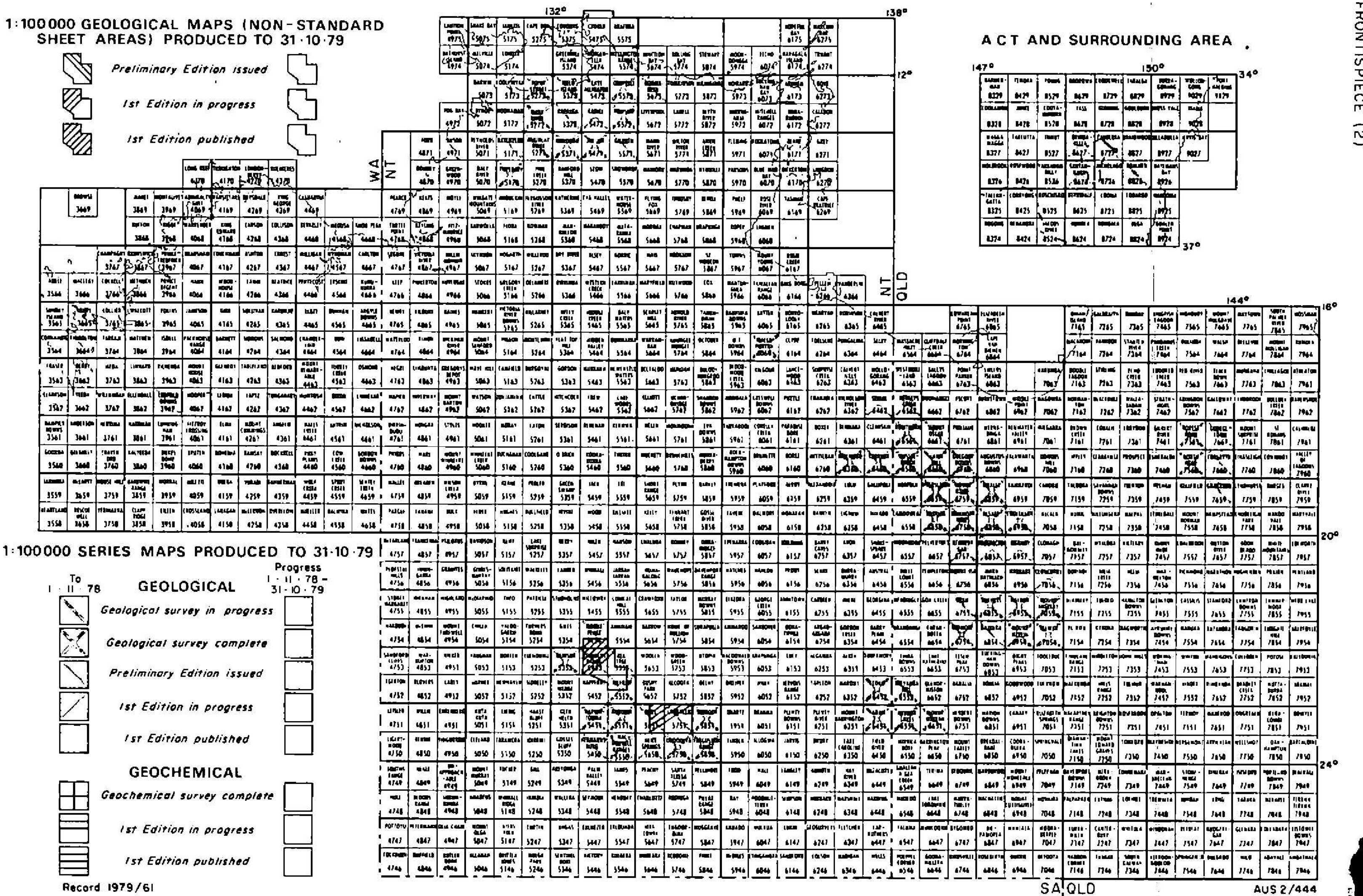

FRONTISPIECE (2)

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GENERAL SUMMARY

SEDIMENTARY SECTION

by

G.E. Wilford

Energy oriented or related projects occupied more than half of the Section staff during the year and many of the studies provided information of direct or indirect benefit to petroleum search. The topics ranged from the specific identification of likely hydrocarbon traps to the longer term determination of basin histories and the development of reliable biostratigraphic zonations. Coal and oil shale studies were initiated at the end of the year and are likely to acquire a greater importance in the Section's activities from 1980 onwards.

The synthesis of information on several sedimentary basins was well advanced at the end of the year; a major bulletin on the geology of the Eromanga Basin (No. 167) was published, and texts with their accompanying geological maps describing the geology of the Wiso, Officer (WA), Ngalia, Carpentaria, and Karumba Basins are with the editors. The production of 1:250 000 scale geological maps and accompanying explanatory notes covering the Canning Basin continued. Preliminary edition maps for the whole basin have now been issued and the remaining First Edition maps and Explanatory Notes should be prepared by mid-1980. Late Proterozoic/Early Cambrian correlations between the Amadeus, Ngalia, and Georgina Basins were investigated using magnetostratigraphic methods in a co-operative study with ANU.

A study combining regional geological knowledge of the Eromanga Basin, source rock geochemistry, interpretation of LANDSAT imagery, and groundwater flow patterns from the Great Artesian Basin study, has made it possible to identify zones protected from flushing, where petroleum entrapment may occur. Follow-up work is planned for 1980.

Fieldwork essential for the revision of the geology of the Canberra 1:250 000 Sheet area was virtually completed by the end of the year. Printing of the Bulletin and the accompanying Tantangara and Brindabella 1:100 000 scale geological maps was well advanced at the end of the period. The geology is complex; work on the area around Canberra City is being done in close co-operation with the Engineering Geology Group. Detailed petrographic and geochemical studies of the many volcanic and intrusive rock bodies is helping to elucidate the geological history.

Cainozoic studies include a field investigation, incorporating drilling, of Tertiary basins in the Alice Springs region. Lacustrine clays are common but carbonaceous sediments are present and lignite is of possible commercial interest. Uranium deposits are also being sought in the area and it is hoped that a regional study of these basins will assist exploration. Palynological and palaeomagnetic methods are being used to date the sediments. A pilot period study of the Oligocene was begun during the year with the main aim of establishing a satisfactory methodology for Australia-wide studies.

Documentation of the study of the Great Artesian Basin was virtually completed. Studies of the isotopes in the groundwater of the Great Artesian Basin, in conjunction with the Australian Atomic Energy Commission, continued, sampling being done in the northern part of the basin. Previous studies have provided valuable information on flow rates and directions, and the origin of the water. A long-term study of the Murray Basin was initiated in co-operation with the Geological Surveys and water authorities of New South Wales, Victoria, and South Australia. Emphasis will be on hydrogeology although work will be done on other resources.

The photogeology and remote sensing group continued to give assistance in the interpretation of colour air photographs for major field projects and did further research into the application of LANDSAT to BMR projects. Ground and helicopter spectral radiometer measurements were carried out over rocks, soil, and vegetation targets in the McArthur Basin region so as to calibrate LANDSAT data as part of a research program aimed at developing computer-assisted techniques to aid in the search for mineralisation. Studies of lineaments from LANDSAT data and aeromagnetic anomalies indicated some relationships between mineral occurrences and lineaments in parts of the Pine Creek Geosyncline.

Staff participated in a 6-week cruise on board the West German research vessel Sonne that was mainly designed to sample pre-Quaternary strata cropping out on the margin of the Exmouth and Wallaby Plateaux. Fossiliferous rocks of Jurassic, Cretaceous, and Cainozoic age were recovered and Early Cretaceous volcanic rocks were shown to be common beneath the Wallaby Plateau. Manganese nodules recovered from the vicinity of the Wallaby Plateau and from the southern Tasman Sea have generally low metal contents.

Great Barrier Reef research continued, aided by the use of a BMR-designed and built portable rotary drill. Cores are giving valuable information on growth rates, and on the changes in environment and in diagenetic processes. Sediment transport studies undertaken in 1979 using suspended-load samplers and current data loggers, are giving indications of the amount of sediment transported across the reefs.

Shallow seismic reflector profiles from west Tasmanian waters show a regional unconformity separating gently folded Miocene limestones from overlying undeformed ?Pliocene to Holocene sediments. Miocene sediments directly underlie the sea floor in several areas. It is planned to complete this study early in 1980.

The Palaeontological Group provided specialist support for the major field projects and in addition made substantial progress in describing, curating, and expanding the national fossil collections. Systematic description of fossils, essential for sound zonation of the stratigraphic column, continued and major studies were published on Tertiary ground-birds and Cambrian agnostid trilobites (Bulletins 184, 172); many smaller studies were published in outside journals. Major works in press or with the editors include studies on Cretaceous pollen and on trilobites from the Georgina Basin. Considerable effort was devoted to processing and dating fossiliferous material from Papua New Guinea and Irian Jaya (see report on Irian Jaya Mapping Project) and from samples derived from the Sonne cruise off northwestern Australia. One member of the group was seconded to ESCAP in Bangkok as stratigrpher to co-ordinate a project (IGCP Project 32) to produce an atlas of stratigraphic columns for the ESCAP region.

MULTIDISCIPLINARY PROJECTS

by

G.E. Wilford

Multidisciplinary studies, in which staff from several Branches work together as a project team, were continued in the Georgina and McArthur Basins during the year. Close integration of geophysical and geological field and office work is a feature of both projects and where possible the work of scientists outside BMR is co-ordinated with that of the project team. J.H. Shergold has been responsible for project co-ordination in the Georgina study and K.A. Plumb in the McArthur. Both projects aim to increase our understanding of basin evolution and particularly those factors that influence mineralisation.

Studies that were completed or almost completed in 1979 in the Georgina Basin project included: a regional re-interpretation of the Adelaidean and Early Cambrian stratigraphy utilising geophysical data and magnetostratigraphic methods; detailed sedimentological investigations of the Cambrian to Ordovician epeiric carbonate units; studies of the major fossil groups including stromatolites, acritarchs, archaeocyathids, trilobites, bradoriids, conodonts, and fish; interpretation and reporting results of the 1977 seismic and gravity survey; geochemical studies of black shale sequences.

Significant results of the research include: the delineation of a major unconformity at the base of the Early Cambrian Adam Shale, the recognition that evaporitic and karst conditions existed at several times in the basins' history, advances in the understanding of petroleum migration, sulphide mineralisation, and dolomitisation, fine zonation of the Late Cambrian using trilobites and of the early Ordovician using conodonts, the interpretation of the Toomba Fault as a high-angle reverse fault, the discovery of anomalously high metal contents in Middle Cambrian black shale at disconformities, and evidence that geothermal gradients have been high in the Hay River area.

Studies in the southern part of the McArthur Basin during 1979 included: seismic refraction/reflection, gravity, and magnetotelluric surveys across the major structural features, an investigation of the application of LANDSAT to the location of mineralised areas, and a continuation of sedimentological studies of various lithological units assisted by drilling.

Further evidence has been obtained that many of the carbonate units accumulated in a sabkha-type environment. This has implications for the movement of brines and the location of mineralisation. A close relationship between certain types of mineralisation and palaeokarst surfaces has also been established. Regional unconformities are widespread and are marked by recrystallisation of underlying carbonates and the silicification of other rock types. Major advances have been made in the correlation of units and in determining their distribution and relationships.

BAAS BECKING GEOBIOLOGICAL RESEARCH LABORATORY

by

A.R. Jensen

The Baas Becking Geobiological Research Laboratory, jointly sponsored by BMR, CSIRO, and the Australian Minerals Industry Research Association (AMIRA), has continued during 1979 to investigate geobiological controls of base metal sulphide mineralisation. In addition, a start has been made on a NERDDC-funded project aimed at investigating the potential for micro-biological processes to enhance the recovery of liquid petroleum from natural reservoirs. Following a successful presentation of the results of the first three years of a five-year metals program at a seminar in March, BMR, CSIRO and a number of companies operating through AMIRA agreed to continue sponsorship of the program. The list of companies numbers eleven and includes some that have not previously sponsored by Baas Becking program.

During 1979, research on the metals program has continued to be concentrated mainly on field studies in and around Spencer Gulf, SA, on ore genesis studies in sedimentary basins, and on laboratory research as an extension of the modern environment studies.

Sedimentological research in coastal areas marginal to Spencer Gulf has distinguished a number of subenvironments each characterised by surface elevation, topography, and frequency of tidal innundation. Relationships are being established between these parameters, the type of algal mat developed, and the groundwater regime in each environment. Concurrent studies are also being undertaken to assess the rate of production by algae of organic carbon, the source of much of the energy required for sulphide formation by sulphate-reducing bacteria. These studies have established the changing pattern in the rates of primary productivity in response to seasonal and diurnal changes and varying salinity of the groundwaters. Additional studies are being undertaken at both Spencer Gulf and Shark Bay, WA, into other complex environmental and climatic factors which influence rates of sulphate reduction. In order to facilitate the application of the results of these studies in modern environments, studies of sulphur isotope patterns characteristic of particular environments adjacent to Spencer Gulf and elsewhere have been continued. The sedimentological and microbiological research in Spencer Gulf has been supported by studies of the chemistry and hydrology of groundwaters and their relation to supratidal carbonate lithification.

The general aim of the ore genesis studies undertaken within the Laboratory is to determine the origin of various stratabound base metal sulphide mineral deposits and to ascertain which characteristics of the deposits could serve as exploration guides. Most of the studies have been on Cu-Pb-Zn mineralisation in the Adelaide Geosyncline and on the Stuart Shelf, SA, but one project has been undertaken on the Eastern Creek deposit, McArthur Basin, NT, and assistance has been given with research into the origin of uranium mineralisation in the Pine Creek Geosyncline, NT. Studies on the Stuart Shelf were concentrated on epigenetic mineralisation in the Pandurra Sandstone and syngenetic or early diagenetic mineralisation in the Tapley Hill Formation. In the Adelaide Geosyncline the studies were of mineralisation at Kapunda and Mount Painter. At Kapunda isotope data for bedded sulphides are characteristic of biological sulphate reduction in a restricted basin, whereas early results from Mount Painter are indicative of magmatic processes. Work on the Eastern Creek deposit is in progress and few results are available as yet. Studies in the Pine Creek Geosyncline are almost complete and a model has been generated which involves derivation of sediments from an Archaean basement with anomalously high uranium values, concentration of uranium in black shale and carbonate and further concentration by low temperature, near-surface processes during a period of peneplanation and karst development.

Sedimentological and biological studies within modern environments have continued to be augmented by laboratory studies where experiments are undertaken to assess the plausibility of models of various processes generated on the basis of field evidence. The principal activity in this field continues to be the monitoring of a system of tanks filled with sediment and brines of varying salinity. Significant changes have been detected during the year in the porosity and permeability of the sediments and algal mat, and on the composition of the overlying and interstitial fluids. Studies have also been made of the changes of the chemistry of the enclosed organic and inorganic components and rates of sulphate reduction.

METALLIFEROUS SECTION

by

R.G. Dodson

Field research continued on all projects listed in last year's report and included a new project in Western Australia. Progress was satisfactory and nearly all objectives were attained despite a heavy commitment by personnel of the Pine Creek Geosyncline Project and of the Petrological, Geochemical, and Geochronological Laboratories to the International Uranium Symposium on the Pine Creek Geosyncline (IUS), held in Sydney, 4-8 June. Progress is shown in Frontispieces 1 and 2.

In central Australia fieldwork was concentrated mainly in the Illogwa Creek 1:250 000 Sheet area, east of Alice Springs, a cooperative effort between geologists of the Metalliferous and Sedimentary Sections, BMR, and a geologist from the Northern Territory Geological Survey. The work included field examination of the recently discovered ruby-corundum prospect at Spriggs Camp. The ruby occurs in calcareous pods, localised in the Irindina Gneiss. East of Alice Springs, a smaller-scale project included research in the GLEN HELEN 1:100 000 Sheet area.

Personnel of the Pine Creek Geosyncline Project, in addition to their planned fieldwork contributed to the IUS by producing two special coloured geological maps of the Pine Creek Geosyncline region at 1:500 000 and 1:2 000 000 scale, by writing seven papers that were presented at the symposium, by assisting in the writing of field excursion guide books and by acting as leaders of field excursions. Despite the added workload, mapping in the McKINLAY 1:100 000 Sheet area was completed and about 20% of the PINE CREEK 1:100 000 Sheet area was completed. Members of the field party carried out a reconnaissance of parts of the Litchfield Block, west of Darwin.

Because of the need for building reconstruction at Mawson Base, no fieldwork was carried out in Antarctica during the year. However petrographic and geochronological work on previously collected specimens continued. Isotopic measurements have not yet confirmed an age of 4000 Ma, claimed for certain rocks in Antarctica by Soviet geoscientists.

Geological investigations in the Mount Isa and Duchess regions, Queensland, have reached a stage where future field research will be confined to brief visits to key localities. Although a much better understanding of the regional geology has been gained, continued investigations have failed to resolve some of the differences of interpretation of the regional stratigraphy.

In the Georgetown Project, fieldwork in the central part of the Georgetown Inlier has been completed; an overall account of the results since the project's inception will be prepared for issue in 1980, together with a special map at 1:250 000 scale. The next phase will be directed towards geological and geochemical research into the Croydon Volcanics, Esmeralda Granite, and the Einasleigh Metamorphics, west of the inlier.

At the invitation of the Geological Survey of Western Australia three BMR geologists assisted in mapping the Sandstone and Youanmi 1:250 000 Sheet areas of the Yilgarn Block. Exposures in the Sheet areas are few and mostly weathered. The geology of the areas mapped consists essentially of Archaean banded gneiss, synforms and fault blocks of greenstone, and granitoid masses surrounding the gneiss and greenstone. The banded gneiss appears to be the oldest rock in the region.

Work of the Volcanological Subsection this year was overshadowed by the death of R.J.S. Cooke, senior Government Volcanologist at the Rabaul Volcanological Observatory, who had been on secondment from BMR since 1971. With an Observatory Technical Officer, E. Ravian, Cooke was killed early in the morning of 8 March by gas and ejecta from the vent on the inner caldera of Karkar volcano. Five partly prepared papers by Cooke will be included in a memoir which he had hoped to edit. Twenty-four other papers on Papua New Guinea volcanological topics have been promised for the memoir, which will be called 'Cooke-Ravian volume of volcanological papers'.

The Petrological, Geochemical, and Geochronological laboratories continued work on some projects, and new research on others started.

Fifteen widely separated occurrences of kimberlite and affiliated rocks are now known in southeastern Australia. The ages range from Permian to Late Jurassic. Location of the kimberlites appears to be related to structures. Pressure/temperature estimates indicate a maximum source depth of about 70 km and a maximum temperature of about 1240°C. As a result the presence of diamond-bearing kimberlites of Permian or younger age is considered unlikely in southeastern Australia.

A comprehensive petrological study has been made of Proterozoic tholeiitic dyke rocks, metapelites, and felsic gneisses from Antarctica.

The first phase of a joint BMR Geological Survey of Western Australia study of rocks of the Pilbara region was completed.

Two crypto-explosion structures were examined during the year. The Goat Paddock cryptoexplosion structure is over 5 km in diameter, and is located in Proterozoic sandstone and siltstone at the northern edge of the King Leopold/Mueller Range in the Kimberley District, WA. The walls of the structure exhibit what are probably the best exposures of the upper crater wall of any impact crater in the world. The Strangways structure, southeast of Katherine, is a circular feature containing abundant evidence of shock metamorphism.

Petrological and geochemical work on host rocks to uranium mineralisation in the Pine Creek Geosyncline continued. The two most striking common features of the ore zones are the tendency for mineralisation to be concentrated in brecciated zones and for it to be associated with chlorite cementing the breccias. The brecciation occurred after a ± 1800 Ma regional metamorphic event.

Ranger 1 orebody No. 3 was selected as the site for an orientation geobotanical and soil geochemistry survey, which is still in progress.

Orientation geochemical surveys were made over parts of the Pine Creek Geosyncline and McArthur River basin, to assess the potential of stream sediment surveys in these regions.

Work on the Araluen Geochemical project continued; 300 stream sediment samples from the rugged coastal escarpment area were collected.

During the year the analytical laboratory handled 3200 samples - 2250 were analysed by quantitative methods for a total of 55 900 element determinations, and 950 by semi-quantitative emission spectroscopy for a total of 16 200 element estimations. 468 samples were examined by the X-ray diffraction technique during the year.

Work continued for the Environmental Water Quality Sub-committee. The activities of the sub-committee are primarily concerned with matters affecting water quality within the ACT and adjoining areas in New South Wales.

The Geochronology Laboratory continued successfully to apply U-Pb zircon and Rb-Sr dating techniques on several projects in the Northern Territory, Queensland, Antarctica, Tasmania, and New South Wales.

GEOLOGICAL SERVICES SECTION

by

E.K. Carter

During the period under review (November 1978 - October 1979) the Section produced 48 reports, papers, and maps with commentaries. This number includes some listed last year which were then in process of issue. Fifteen were for publication and 33 for issue as unpublished Records or Professional Opinions; of these 26 were published or issued, and the remainder are at various stages of reproduction.

The trend in the work of the Engineering Geology and Hydrogeology Subsection away from activities in the A.C.T., noted in previous years, continued. Services during construction of the Ginninderra Sewer Tunnel were completed, and the completion report is being prepared. A report on the sand and gravel resources of the Canberra region, which shows ample resources within economic distance for the next twenty years, was completed and issued. Further progress was made with the preparation of 1:10 000 scale engineering geology maps of Canberra: one is being fair-drawn, three have been compiled, and two are being compiled; notes have been completed for two of the maps. Mapping of excavations was maintained during the year and several minor engineering geology investigations were undertaken. Five groundwater pollution studies were maintained or undertaken, and the monitoring of groundwater conditions in the A.C.T. and at Jervis Bay, and the study of Lake George, continued. Further progress was made with the joint project with CSIRO to determine the hydrological regime of the Upper Yass River representative basin.

Construction of the Telecom cable tunnels, central Melbourne, began in October 1979. The arrangement whereby BMR provided oversight of the pre-construction geological investigation and produced the geological report for design purposes will continue during construction. Further assistance was given to the Australian Development Assistance Bureau (ADAB) in the control and supervision of groundwater investigations for town water supply in South Sumatra. A new groundwater investigation carried out for ADAB by Section officers on Niue Island, South Pacific, resulted in the location and development of ample supplies of water for irrigation and town supply purposes. Niue is a coral island with a volcanic basement, and the distribution, thickness, and quality of the freshwater lens beneath the island were delineated.

A research project was initiated for the Office of the Supervising Scientist. Field work began in July on a study of the groundwater regime in the cover to the bedrock, below the valleys of Magela and Cooper Creeks, Alligator Rivers Region, N.T. These valleys could be affected by uranium mining nearby and the investigation is part of a long-term study to monitor and predict the effect of the mining. Mapping, surface infiltration tests, and drill hole logging and testing, were carried out.

Fourteen maps were edited by the Map Editing and Compilation Group compared with 23 in the previous period. Six maps for the BMR Earth Science Atlas of Australia, compiled by the Group, are with the printer, and notes for several of them are complete (two by officers of other groups). Compilation of the 1:5 000 000 scale geology of Australia map, for the Atlas of Australian Resources, was completed for the Division of National Mapping.

The Central Register of Stratigraphic Names and Definitions was maintained throughout the year. The number of names and definitions reserved or otherwise recorded (713) was significantly greater than last year (519). The usual lists of variations were distributed. During the year the Stratigraphic Indexer and one officer of the ADP Section implemented a computer-based data system. All incoming data are now being recorded on computer and progress is being made in recording previously card-indexed data.

A review of the geological occurrence of fluorite in Australia, started last year, continued.

Slightly fewer visitors (722) called at the Geological Museum than last year owing to a sharp reduction in the number of school groups. Other information services were maintained by the Museum staff, including displays at five exhibitions, participation in school excursions, supply of teaching sets, and identification of mineral and rock specimens. Additions to the collections were mainly by exchange, with some purchases. The recent rise in the price of gold and publicity for metal detectors have been reflected in enquiries. A field assessment, followed by laboratory studies, was made of a recent discovery by an exploration company of gem-quality rubies in the Harts Range, Central Australia. Some ruby specimens were received by the Museum, and the curator wrote a paper, jointly with R.G. Warren, describing the deposit and rubies from it.

The Transit Officer handled 7430 specimens for thin-sectioning, chemical analysis, or instrumental determination.

SEDIMENTARY SECTION

Head: G.E. Wilford

PROVINCE STUDIES

BASIN SYNTHESES

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

A major bulletin on the geology of the Eromanga Basin (No. 167) was published and texts and accompanying 1:500 000 or 1:1 000 000 scale geological maps describing syntheses of the geology of the Wiso, Officer (WA), Ngalia, Carpentaria, and Karumba Basins are with the editors. A preliminary edition of a 1:500 000-scale geological map of the Ngalia Basin was issued and a map at the same scale summarising airborne magnetic, gravity, and seismic data on the basin was compiled. The 1:250 000 scale geological maps and explanatory notes covering these basins are now published (see frontispiece 1).

Studies of the Georgina and McArthur Basins are reported under 'Multidisciplinary Projects'.

CANNING BASIN MAPPING

by

R.R. Towner

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

The objectives of this project are to study the geology of the Basin as well as to re-map it in sufficient detail to enable the preparation of all outstanding 1:250 000 First Edition geological maps and explanatory notes. Second Edition maps and notes of some Sheet areas are also to be published. The project is a joint one with the Geological Survey of Western Australia. Field investigations started in 1972 and were completed during 1977.

By the end of October, the draft report of the 1977 field mapping of the onshore west Canning Basin, to be published as a Record, was well advanced.

The preliminary geological editions of PENDER, BROOME, LA GRANGE, MANDORA, MUNRO, McLARTY HILLS, ANKETELL, and PORT HEDLAND, were released; while the preliminary edition of YARRIE is expected to be released in early 1980.

Explanatory Notes for RYAN, WILSON, URAL, TABLETOP, SAHARA, PERCIVAL, together with Second Edition MOUNT BANNERMAN and CORNISH were released during the year, while MORRIS and RUNTON were in the final stages of printing. Second

Edition Explanatory Notes for NOONKANBAH, MOUNT ANDERSON, DERBY, and PATERSON RANGE together with JOANNA SPRING (First Edition) were with the editors at the end of October.

EROMANGA BASIN HYDROCARBONS

by

B.R. Senior

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

The hydrocarbon potential of the Eromanga Basin sequence in southwest Queensland was evaluated in terms of source rock geochemistry, structure, and groundwater hydrodynamics. Interbedded coal, carbonaceous mudstone, and siltstone within the Jurassic and Lower Cretaceous are fair to very good source rocks for oil. Approximately the lower half of the Eromanga Basin sequence is marginally mature or mature, depending on thickness and variations in geothermal gradients. Linear features interpreted from LANDSAT imagery and aerial photographs indicate the probable presence of major fracture systems as some features coincide with faults delineated by seismic surveys. Groundwater flow provides a mechanism for moving indigenous (Eromanga Basin) or derived (Cooper or Adavale Basins) hydrocarbons through the region. Faults with displacements of 15 m or more, which impede groundwater flow, could trap and protect petroleum from the effects of predominantly southwesterly groundwater movement. The results of this study were presented at the 8th BMR Symposium and will be published in the BMR Journal (Senior & Habermehl, in prep.). Further work, including acquisition of new geophysical data, is planned for 1980.

LACHLAN FOLD BELT (CANBERRA AREA)

by

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

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

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

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

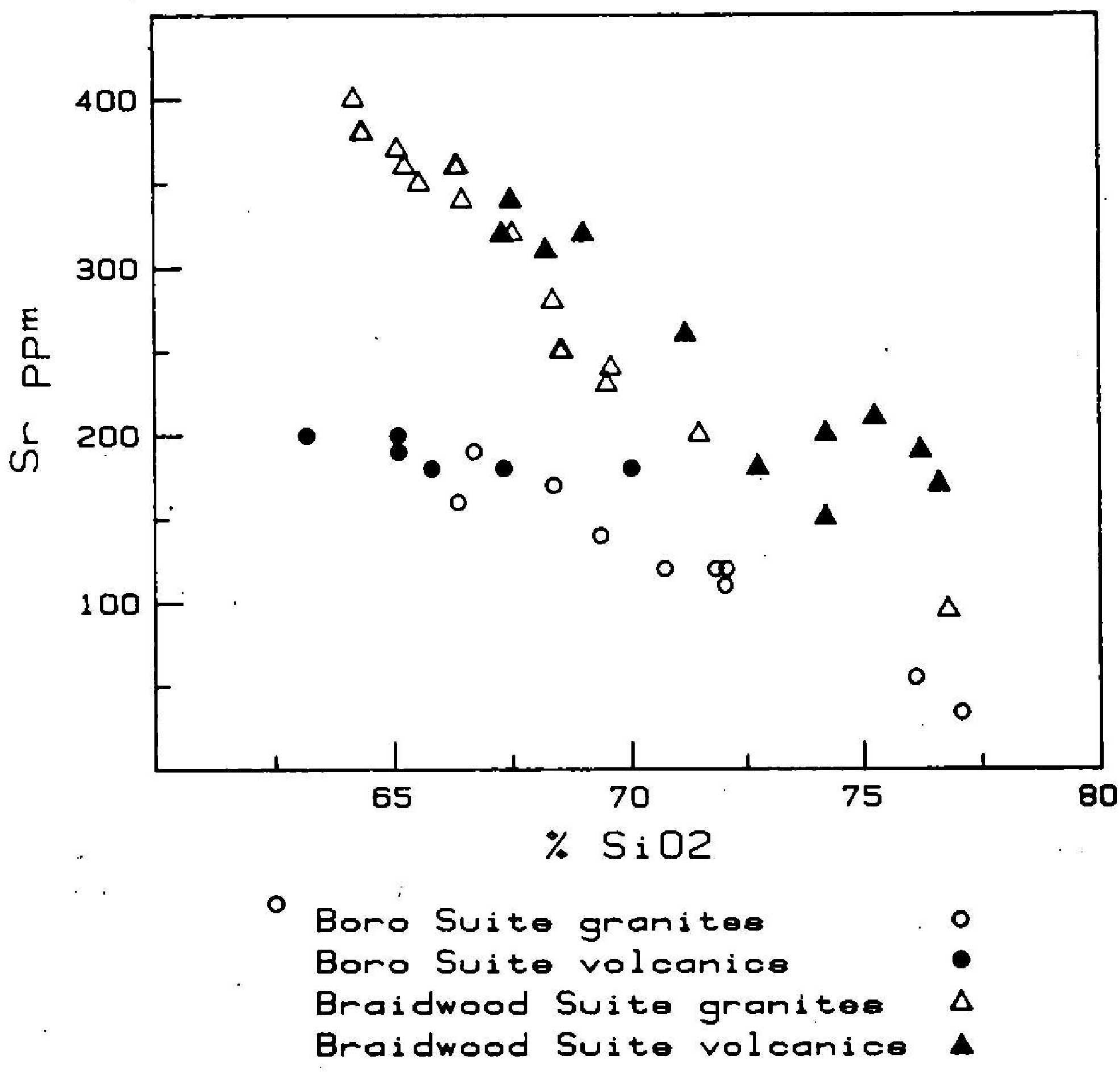
The descriptive Bulletin was edited and sent to press during 1979. Colour proofs of the 1st edition colour maps have been received.

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

Systematic field research, which commenced in October 1977, was virtually complete by April 1979, with only about 2 percent still to be done in areas made inaccessible by wet weather in the first half of 1979. Limited fieldwork was also done on the adjacent Batemans Bay 1:100 000 sheet when problems could not be resolved within the Araluen Sheet.

Particular attention was paid during fieldwork to the structure of the Ordovician rocks close to the Comerong Rift Zone. East of the zone, a pre-Nelligen Granodiorite, meridional isoclinal fold system (F1) has been overprinted by down-buckling (F2) against the eastern bounding fault of the Comerong Rift Zone, producing both recumbent and downward-facing F1 folds with tectonic transport from east to west. West of the zone a similar downbuckling has occurred against the western bounding fault of the zone near Woolla Creek. Recumbent and downward-facing F1 folds have in this case been transported tectonically from west to east. Thus the rift zone has controlled the downbuckling and it is likely that F2 occurred when Upper Devonian sediments within the rift zone were highly folded and cleaved.

The systematic collection of samples for whole-rock geochemistry was also an important feature of the fieldwork. Analytical results from the Boro and Braidwood granitoids and the Long Flat Volcanics confirmed earlier petrographic evidence that each granitoid is comagmatic with a corresponding suite of volcanics. In particular, the strontium content of the two granitoids separates them into two suites (Fig. S1) - the Braidwood Suite has much higher strontium at the same silica level as the Boro Suite. Rocks related to both granitoid suites are found in the Long Flat Volcanics, but can only be separated by their strontium content. No petrographic or field criteria can be used to separate them.



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M(G) 689

Fig. S1 Plot of Sr against SiO_2 for volcanic and granite members of the Boro and Braidwood Suites, Araluen 1:100000 Sheet area.

Chemical analyses of the 'Mount Donovan basic complex', east-trending dolerite dykes in the Boro and Braidwood granitoids, and basalts from the Comerong Volcanics show all three groups to have similar compositions, the magma type being similar to continental tholeiites transitional into alkali basalt. However, the stratigraphic age of the Comerong Volcanics (mid- to late Devonian) is at variance with preliminary radiometric dating of the 'Mount Donovan complex' and the dolerite dykes, which give a Carboniferous age (355 m.y.). Further dating will be needed to resolve this conflict.

The results of a soil and stream sediment geochemical survey undertaken concurrently with the mapping are given in the Metalliferous Section report.

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

An evaluation of the geology continued during the year.

Ordovician

Rocks are exposed mainly in the Cullarin Horst and Gidleigh Block, but they also occur as inliers in the Canberra and Captains Flat Troughs. It is not yet possible to recognise a consistent stratigraphic succession, but a number of rock types can be mapped:

(a) Turbidites - These consist of repeated units of sandstone, siltstone, and shale, characterised by graded-bedding, bedding plane irregularities, and some cross-bedding. Thin grit bands (up to 2.5 cm), impure calcareous bands, and rhythmic sedimentation (alternating siltstone-shale laminations) also occur. Stratigraphic names in current use are Pittman Formation, Foxlow Beds, Birkenburn Beds, and Adaminaby Beds.

(b) Black carbonaceous shale - Graptolites collected from this lithology are of late Ordovician age (Eastonian-Bolindian). Black shales often associated with cherts, appear to be characteristic of the later stages of sedimentation in the 'Monaro Trough', when there were stable conditions (less turbidite-slope association) and a lower-energy environment. The outcrop pattern of black shales along the horsts' margins suggests that the horsts are anticlinorial structures. Stratigraphic names in current use are the Acton Shale, Picaree Formation, and Bullongong Shale.

Silurian

Rocks occur mainly in the Canberra and Captains Flat Troughs.

(1) Llandoverian rocks comprise a proximal flysch unit which is an apparent continuation of sedimentation from the Ordovician. There is no physical evidence for an unconformity at the base of the Silurian. The occurrence of Monograptus exiguus gives a Late Llandoverian age to part of this sequence in the Canberra area (Opik, 1954). Rocks of this age are fairly widespread, being known near Michelago and south of Goulburn, and their occurrence elsewhere is likely, particularly along the Lake George scarp and within the Captains Flat trough. However, in the absence of fossils it may be necessary to correlate using lithological similarity to known associated sandstone units. Stratigraphic names in current use are Black Mountain Sandstone, Murrumbateman Formation, and State Circle Shale.

(2) Wenlock sediments consist of shallow-marine shale, siltstone, sandstone, and discontinuous limestone. They rest unconformably on the Llandovery in the Canberra area. This early Wenlockian unconformity (Quidongan Orogeny) introduced a major change in the geological environment, denoted by the advent of shallow-marine conditions with a shelly fauna, and the gradual onset of volcanism. Stratigraphic names in current use are Canberra Group, Fairbairn Group, Westmead Park Formation, and Narrabundah Ashstone.

Acid volcanism commenced in the late Wenlock with the deposition of discontinuous volcaniclastic units which pass upwards into a thick subaerial ignimbrite pile interfingering with marine sediments. The oldest volcanic unit that can be recognised in the Canberra area is the Hawkins Volcanics (with which are correlated the Painter, Ainslie, and Gladefield volcanics). The Hawkins Volcanics are in part equivalent to the Walker volcanics (M. Owen pers. comm.). Shelly marine fossils from shale within the Walker Volcanics near Coppins Crossing (D. Strusz pers. comm.), support the Wenlockian age deduced by mapping between Yass and Canberra coupled with geochemical differentiation of the volcanic units.

(3) Ludlow - The only sediments in the Canberra area datable as Ludlovian on fossil evidence are the Yarralumla Formation - a shallow-marine unit consisting of shale and occasional thin limestone representing a quiescent

period in volcanic activity. A new phase of volcanicity commenced with the Deakin Volcanics - a heterogeneous unit containing tuff, tuffaceous sandstone, and rare impure limestone near its base, passing up into banded rhyodacite. The Mugga Porphyry is an ignimbrite unit at the base of the Deakin Volcanics apparently overlapping the Hawkins Volcanics and Yarralumla Formation. The Deakin Volcanics are overlain by a further sequence of rhyodacitic flows and interbedded Early Ludlaw marine sediments known as the Laidlaw Volcanics - the volcanics have been dated at 420 m.y. (M. Owen pers. comm.).

The status of the Colinton Volcanics is presently unclear, but M. Owen (pers. comm.) has demonstrated that geochemical data for this unit plot in the same field as the Deakin and Laidlaw Volcanics, which suggests a Ludlovian age. It is therefore possible that the underlying Capannana Beds may be a correlative of the Yarralumla Formation.

(4) Mapping by Henderson (1975) in the Gooromon Ponds area has now made it possible to extend northwards the stratigraphic units recognised around Canberra (M. Owen pers. comm.). In this area the Ainslie and Painter Volcanics (members of the Hawkins Volcanics) underlie the Yass Formation (Early Ludlow) and overlying Laidlaw Volcanics, which in places appear to interfinger with the Deakin Volcanics, the latter unit wedging-out northwards.

(5) The Silurian stratigraphy in the Captains Flat Trough, originally established in the Lake George Mine by Glasson (1957), cannot be recognised with certainty between Bungendore and Hoskinstown. Correlatives of the Wenlockian strata nearer Canberra may be present, but tentatively it has been decided to divide the rock units into (a) a lower marine unit probably equivalent to the Canberra Formation and (b) an upper volcanic unit, the Captains Flat Formation, probably equivalent to the Hawkins Volcanics. The much reduced thickness of acid volcanics in the Captains Flat Trough, the development of deeper-water conditions and the presence of basic volcanic units suggests the Ludlovian may be absent.

Cainozoic - From April to June 1979, five stratigraphic holes were drilled to investigate Cainozoic sedimentation and weathering profiles in the Lake George basin - Molonglo plains area. All the holes were geophysically logged using SP, resistivity, neutron, and gamma ray techniques.

A sequence of lacustrine and fluvial clay, silt, sand, and gravel several tens of metres thick has been provisionally dated by pollen as Quaternary in age (E. Truswell, pers. comm.). These unconsolidated sediments overlie a strongly weathered profile in Palaeozoic bedrock, whose formation has been dated as late Tertiary using palaeomagnetic methods (M. Idnurm, pers. comm.). Evaluation of the drilling results is not yet complete.

Intrusive rocks

(1) Acid intrusives are confined to small 'I-type' granitoid bodies which postdate Silurian sediments and acid volcanics. This has been confirmed by a recent age determination on the Sutton granite of 410 ± 4 m.y.

Numerous discontinous north-trending bodies of sheared and foliated quartz-feldspar-porphyry cut Ordovician flysch along the Lake George escarpment and in a belt east of the Bungendore-Hoskinstown Road. A porphyry near Mount Murray station dated at 407 ± 4 m.y. suggests that these intrusions may be offshoots of a more extensive granite body at depth, perhaps being feeders for Siluro-Devonian volcanics long since removed by erosion.

'High level' unfoliated quartz-feldspar-porphyry intrusions are associated with Silurian volcanics in the Canberra Trough, notably at Mount Neighbour, Lambrigg homestead, Gold Creek homestead and along the Queanbeyan-Cooma Road. These represent feeders for the surrounding volcanic pile; at some localities (Briarwood homestead, Red rocks gorge and Jerrabomberra homestead) there are xenoliths of a similar coarse-grained porphyry in the volcanic sequence.

(2) Basic intrusions can be grouped into (a) amphibolite, coarse-grained hornblende gabbro, dolerite, and epidiorite with a strong northerly trend and foliation associated with an F_2 fold phase, and (b) unfoliated dolerite and gabbro trending north and northwest which postdate an F_2 fold phase and are likely to be post-Paleozoic in age. These intrusions cut Silurian acid volcanics and sediments.

Structure

The suggested structural history of the sheet area comprises (a) an early F_1 fold phase (Benambran?) denoted by downward-facing folds and an early biotite-segregation foliation, (b) a minor earth movement (Quidongan) demonstrated by unconformities at State Circle and Burra Creek and (c) an F_2 fold phase (Bowning or Tabberaberran?) with plunging folds and a cleavage/foliation trending approximately N-S. Late-stage kink folds with shallow-dipping axial planes appear to relate to zones of reverse faulting, e.g. Lake George Fault, whereas kink folds with steep axial planes seem to be related to strike-slip faults, e.g. Googong area.

Lineament analysis shows that major fractures group N-S and NW-SE, similar to major fault directions. Analysis of joint stereonets from engineering geology reports suggests a similar pattern.

Block-faulting in the Cainozoic is determined largely by pre-existing zones of N-S-trending Palaeozoic reverse faults. At least some of these movements postdate a middle to late Tertiary weathering event, as the thick soil profiles preserved in the Canberra and Captains Flat Troughs appear to be thin or non-existent in uplifted horst blocks.

Metamorphism

An early high-grade regional metamorphic event (M_1) is characterised by psammitic, pelitic, and knotted schists which may reach up to the amphibolite facies of regional metamorphism. It is from these rocks that evidence can be demonstrated for two fold phases in the Ordovician. An F_1 phase is deduced from biotite segregation laminae which may only sub-parallel the original bedding and therefore represent an early foliation (cleavage). The segregation laminae have been folded in a second deformation (F_2).

A local metamorphic event (M_2) is associated with the intrusion of the 'hot' I-type Sutton granite. The results are spotting in Ordovician flysch and a contact aureole - an easily mappable feature. The spots are porphyroblasts of cordierite, now altered to sericite and quartz. A similar local metamorphism of the Yarralumla Formation along Red Hill ridge (Canberra) is caused by a tonalite underlying the Federal Golf Course; in this case calc-silicate rocks have formed.

A late low-grade regional metamorphic event (M_3) is associated with the F_2 phase of folding. This event appears to have <u>post-dated</u> granitoid emplacement, as augens of cordierite retrograded to sericite and quartz are drawn out parallel to an F_2 cleavage within the contact metamorphic aureole surrounding the Sutton Granite.

Mineralisation

(1) Gold occurs mainly in an arcuate zone of mineralisation around the SE margin of the Sutton Granite, in narrow meridional quartz veins within late Ordovician flysch deposits. The distribution of gold prospects is affected by (a) the northerly extension of the Queanbeyan Fault, which bounds the western margin of the Sutton Granite and (b) a contact metamorphic zone around the eastern margin of the Sutton Granite - the gold appears to concentrate along the margins of this metamorphic zone.

(2) Base Metals - Massive Cu-Pb-Zn-Ag strata-bound lenses within sequences of felsic volcanics have been well documented at Captains Flat and Woodlawn - both just beyond the edges of the Sheet area. A number of companies have taken up exploration licences north of Hoskinstown and the ACT border in recent times, but without success to date.

LACHLAN FOLD BELT GEOPHYSICAL PROJECT

STAFF: A.N. Yeates

During 1979 a number of new and ongoing geophysical investigations in the Lachlan Fold Belt were drawn together into a project to study the geophysics of the region. The project aims to establish a framework for understanding the geophysical response of the crustal and surface geology of the region, including its mineralised domains and mineral deposits. Establishment of this framework is intended to permit better use of the large BMR regional geophysical data bank covering this region.

In 1979 work was concentrated in the NSW section of the Fold Belt and employed personnel of the Geophysical and Geological Branches and the Geological Survey of NSW. Key elements of the work were the completion of regional airborne geophysical surveys, investigation of the source of regional geophysical features, and a continuation of crustal studies and of geophysical studies of mineral deposits in the Cobar area. A full account of the project is included in the Geophysical Branch Summary of Activities for 1979. Geological Branch contribution to the project was principally the secondment of A.N. Yeates to the project from March 1979.

Mr Yeates has been principally involved in field and laboratory studies of the source and geological characteristics of regional geophysical features. Field visits have been made to representative outcrops of the major rock systems within the Fold Belt, and to areas where gravity and magnetic anomalies are present. At each of 800 sites, geological notes have been made and rock physical properties measured, including magnetic susceptibility and gamma-spectrometer response. Samples collected are being further studied in the laboratory where measurements are being made of magnetic susceptibility and remanence, density, and porosity. In addition, thin and polished thin sections of these samples are being prepared. The field work to be undertaken in NSW will be completed by December 1979 and a report on laboratory and field work will be prepared during 1980. A preliminary account of the regional geophysical characteristics of the NSW section of the Fold Belt has been prepared for presentation at the 4th Australian Geological Convention in Hobart January 1980.

CORRELATIONS BETWEEN CENTRAL AUSTRALIAN BASINS

by

A.T. Wells

MAGNESTOSTRATIGRAPHY STUDIES

Magnetostratigraphic tests of the correlation of Proterozoic formations in the Amadeus, Ngalia, and Georgina basins were made in collaboration with Dr P. Burek of the Research School of Earth Sciences. One of the formations selected was the Yeundumu Sandstone in the Ngalia Basin as there was an established magnetostratigraphic reference section in a similar part of the sequence in the Amadeus Basin. The lower part of the Yuendumu Sandstone was found to have mixed polarities and could be correlated with the upper part of the Arumbera Sandstone I (Proterozoic) and Arumbera Sandstone II-III (Early Cambrian). Arumbera Sandstones II and I are separated by an unconformity and subsequent photo-interpretation and field observations indicated a break in the Yuendumu Sandstone, which together with the palaeomagnetic data indicates that the lower part of the Sandstone is best correlated with the upper part of Arumbera Sandstone I and thus is latest Proterozoic in age.

These results plus the results of similar tests on Proterozoic rocks from the Georgina Basin were published in the BMR Journal.

EASTERN OFFICER BASIN - AMADEUS BASIN LITHOLOGICAL CORRELATIONS

A field reconnaissance was made of the stratigraphic sequence in the eastern Officer Basin at the invitation of the South Australian Department of Mines & Energy. The purpose of the visit was to make comparisons of the Cambrian to ?Devonian sequence in the eastern Officer Basin with the Amadeus Basin. Because there is a dearth of fossils in the Officer Basin sequence it is necessary to resort to alternative methods of age determination and it was anticipated that correlation with the Amadeus Basin would assist in solving this problem.

Direct comparisons are possible between the Devonian and Ordovician sequences, and although regional facies changes in the Cambrian groups are comparable, precise matching of formations is not possible. Fan conglomerates and evaporitic environments are common to both Cambrian groups.

Lithostratigraphic correlations are illustrated in Figure S2.

AUSTRALIA-WIDE STUDIES

CAINOZOIC WEATHERING

STAFF: B.R. Senior

This project, which was aimed at research into the origin, age, and distribution of weathered profiles and their relation to landform evolution in southwest Queensland, is now complete. Two papers were published during the year. The first (Senior, 1979) describes the mineralogy and geochemistry of parent (Winton and Eyre Formations) and weathered rocks (Morney profile, Canaway profile, Curalle silcrete profile, Haddon silcrete). The second paper, in collaboration with Professor J.A. Mabbutt (University of NSW), proposes a method of defining deeply weathered rock units, within a scheme which is based on accepted principles and concepts of the Australian Code of Stratigraphic Nomenclature.

By-products of this research included age determination of iron oxide-enriched layers within weathered profiles using palaeomagnetism (Idnurm & Senior, 1978), and an exploration technique for locating ironstone bodies which

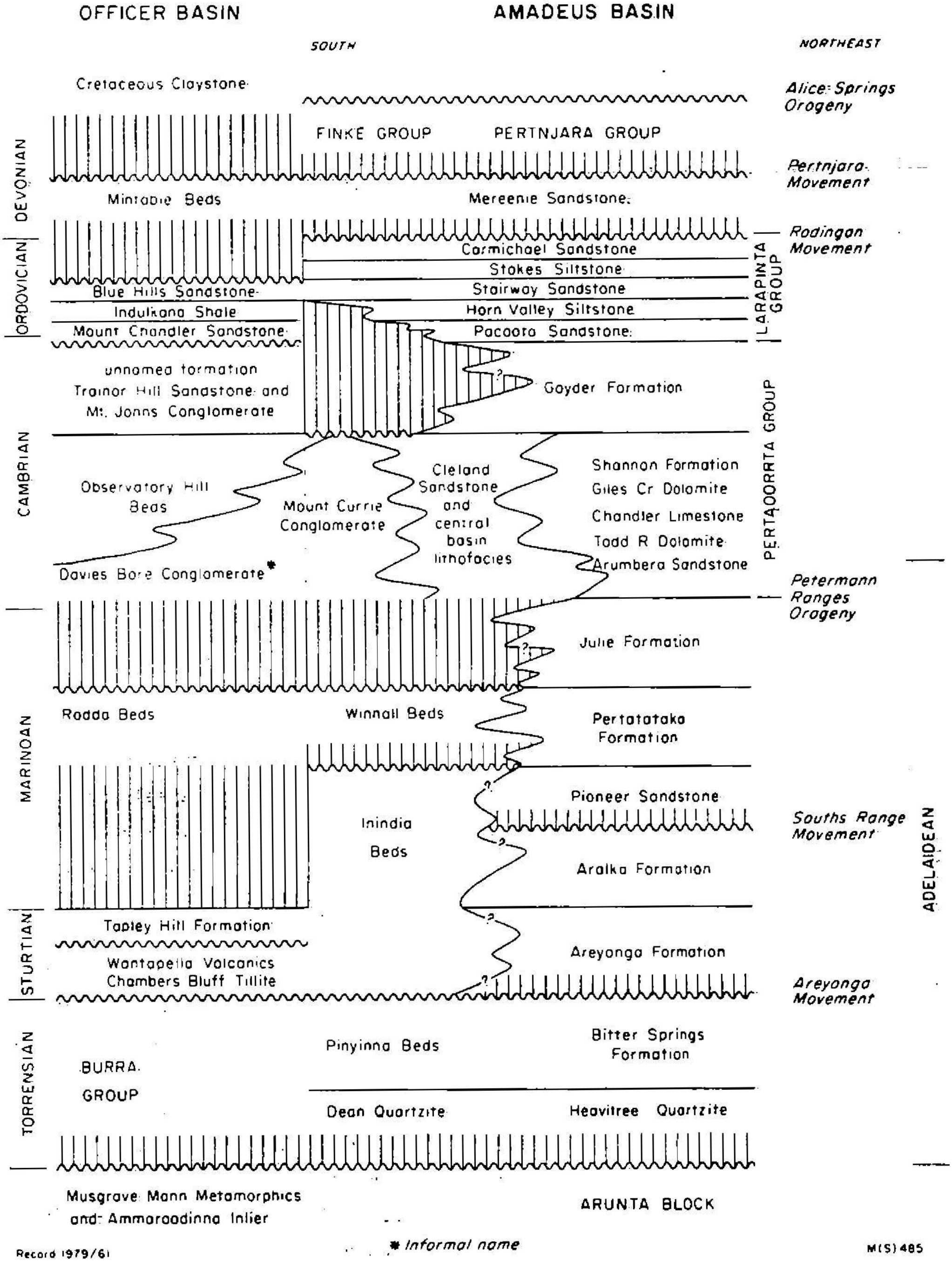

Fig. S2 Lithofacies correlation — eastern Officer and Amadeus Basins.

are the host rocks of precious opal in southwest Queensland (Senior et al., 1977). The close association between structure and landforms within this region led to the discovery of hitherto unknown structural trends which may have a bearing on the entrapment of hydrocarbons within the Eromanga Basin sequence (see 'Eromanga Basin Hydrocarbons').

CAINOZOIC BASIN STUDIES, ALICE SPRINGS REGION

by

B.R. Senior

STAFF: B.R. Senior, E. Truswell (part-time), M. Idnurm (part-time).

This project, commenced early in 1979, is a multidisciplinary study aimed at Australia-wide research into the sedimentation, age, and weathering history of Cainozoic epicratonic basins. In the long term the project will involve a comparative appraisal of both onshore and offshore Cainozoic sedimentary rocks, and involve the disciplines of palynology, palaeomagnetism, geology, and geomorphology.

Field work during 1979 included shallow stratigraphic drilling in the southeastern part of the Ti Tree Basin (Alcoota 1:250 000 Sheet area) and into an unnamed Cainozoic sequence in the Illogwa Creek 1:250 000 Sheet area. Outcrop sections of Cainozoic rocks were measured at widely spaced localities throughout the southeast corner of the Northern Territory.

Preliminary results indicate that the southeastern Ti Tree and Waite Basins (Alcoota and Huckitta 1:250 000 Sheet areas) and the unnamed Cainozoic sequence in depressions to the east of the Harts Range (Illogwa Creek 1:250 000 Sheet area) had a similar depositional history. The oldest sedimentary rocks are green, pyritic mudstones which appear to have been deposited under reducing conditions within a series of interconnected lakes. Cores of this mudstone show 'colloidal' patches of olive-green claystone, but otherwise lack sedimentary structure and organic material. The homogeneity of these mudstones indicates quiet water deposition, coupled with low input of terrigenous detritus from the nearby Macdonnell Ranges. The mudstones pass abruptly into overlying poorly sorted clastics, which were probably deposited rapidly in a series of piedmont fans. These sediments are strongly weathered and contain abundant iron oxide pisoliths and scattered charcoal-like fragments.

The Hale River Basin, which is an isolated epicratonic basin surrounded by the Macdonnell Ranges (Alice Springs 1:250 000 Sheet area), has undergone a different sedimentation history from those mentioned above. The sequence there is up to 80 m thick, and is mainly fine-grained arenite with beds of lignite, carbonaceous mudstone, and siltstone. The upper part is lateritised and unusual strongly ferruginised profiles occur locally. The most complete section of the Hale River Basin sequence crops out on the southern slopes of Claraville Hill, at the eastern end of the basin.

Palaeomagnetic age determinations are being made on laterite profiles developed in Arunta Complex and Cainozoic rocks, and palynological studies are in progress on drill cuttings from the Hale River Basin. It is hoped that this work, in combination with geological and geomorphological considerations, will lead to a better understanding of the evolution and economic mineral potential (uranium, lignite, and gold) of the Cainozoic sedimentary basins of this region. New Cainozoic data are being incorporated in the Illogwa Creek 1:250 000 Sheet area (second edition) which is currently being compiled.

EVAPORITES IN AUSTRALIA

STAFF: A.T. Wells

Editing of a Bulletin on Australian evaporite occurrences, and drafting of the accompanying figures, commenced during the year.

New information on the extent of major evaporite occurrences in Australia was obtained during stratigraphic drilling by the South Australian Department of Mines & Energy in sediments of the Cambrian Observatory Hill Beds beneath the Arckaringa Basin and the Officer Basin. The evaporites beneath the Arckaringa Basin are principally halite whereas those in the eastern Officer Basin are possibly lacustrine in origin and contain an entirely different suite of evaporite mineral species. The results of these new discoveries will be incorporated in the Bulletin.

PERIOD STUDIES

W.J. Perry

This Project was begun in 1979 with the limited objective of establishing a satisfactory method of studying a geological period Australia-wide. Six geologists including four from the Palaeontological Group were programmed to contribute to the project on a part-time basis. They selected the Oligocene Epoch for a pilot study because of the relatively restricted distribution of known Oligocene rocks in Australia.

Owing to other work commitments progress has been slower than expected; however, a specialist from the ADP Application Section has designed two coding forms in collaboration with members of the Project Group, to enable data to be entered into a data base in BMR's Hewlett-Packard computer.

The coding forms have provision for the entering of information including bibliographic details of reports consulted, locality of wells or surface geological sections including 1:250 000 and 1:100 000 map Sheet numbers and geographical coordinates, surface elevation, depth to tops and bases of relevant units (formations or time-stratigraphic), nature of contacts with over- and underlying units, rock types, zone, zone author, absolute age, sandstone/shale and limestone/anhydrite percentages, sample type, associated mineral deposits, and in terms of keywords, palaeogeography and subjects of importance covered in the reports consulted, for example palaeontology, and whether the information comes from an open file or confidential report.

Some information from well completion reports on the Gippsland and Murray Basins and the Canning offshore area has been coded and entered into the data base, but much compilation work remains to be done, and the pilot study is expected to be completed in 1980.

TILLITE STUDIES

STAFF: J.M. Dickins, M.J. Jackson, K.A. Plumb, R.R. Towner, M.R. Walter, A.T. Wells

Papers describing tillite-bearing units of Permian and/or Precambrian age from the Canning, Officer, Bonaparte Gulf, Kimberley, Georgina, Ngalia, Amadeus, and Victoria River Basins, and the Duchess area of northwest Queensland were written as contributions to a book 'Pre-Pleistocene Tillites: a Record of Earth's Glacial History', a contribution to Project 38 of the International Geological Correlation Program. Individual papers are listed under 'Publications and Records'.

HYDROGEOLOGICAL STUDIES

GREAT ARTESIAN BASIN

by

M.A. Habermehl

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

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

Following the commencement of the study in 1971, existing geological, geophysical, and hydrological data from BMR and State Geological Surveys and Water Authorities were compiled, transcribed, computer-processed, and stored from 1972 to 1974 with assistance from staff provided by BRGM-Australia on a contract basis.

Analysis of the hydrogeological information resulted in the definition of an aquifer model of the Great Artesian Basin. It combines the many aquifers in the Mesozoic sedimentary sequence (consisting of continental quartzose sandstones of Triassic, Jurassic, and Cretaceous age) into two confined aquifers, two confining beds (Cretaceous mudstone and siltstone), and a near-surface watertable. The latter approximates a constant head boundary compared with the changing heads of the confined aquifers.

The digital computer model GABHYD is based on finite difference approximations of the Hantush approach for leaky aquifers. The GABHYD model replaced the original GABSIM model, and consists of a group of computer programs developed from 1975 to 1977. It operates on a square grid with a separation of 25 km between the gridlines, and determines for each node of each confined aquifer the complete water balance. Model output consists of all potentials and discharges for each major time step and each grid node. Calibration was carried out during 1977 and 1979, and application runs were made in 1978.

The simulation model's predictions of the future hydraulic behaviour of the basin following management interventions can be used for assessment, planning, and management purposes, on a regional scale, of the basin's artesian groundwater resources.

Some results of the hydrogeological study and from the use of the computer model have been described in previous Annual Summaries of Activities. During 1979, documentation of the hydrogeology of the Great Artesian Basin and of the GABHYD computer programs and operating systems continued, and several papers were prepared.

A paper - 'Groundwater resources of the Great Artesian Basin' - by Habermehl & Seidel was presented by Habermehl at the Symposium on The Land and Water Resources of Australia - Dynamics of Utilisation - of the Australian Academy of Technological Sciences in Sydney from 30 October to 1 November 1978, and prepared for publication in the Proceedings of the Symposium which were issued during 1979.

Papers, 'The Great Artesian Basin, Australia' by Habermehl, and 'Application of the GABHYD groundwater model of the Great Artesian Basin' by Seidel, were prepared for the BMR Journal. These papers deal with (1) groundwater exploration and development, (2) geology, (3) groundwater hydrology, (4) modelling the groundwater system and assessment of the groundwater resource and its use; and (5) with the definition of the model prototype, data preparation and calibration, features and limitations of the model, model operations, and sample application.

A related paper, 'Structure, hydrodynamics and hydrocarbon potential of the central Eromanga Basin, Queensland', by Senior & Habermehl is described in this Summary in the section 'Eromanga Basin Hydrocarbons'.

ISOTOPE HYDROLOGY OF THE GREAT ARTESIAN BASIN by M.A. Habermehl

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

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

Water samples from artesian wells are analysed where appropriate for the environmental isotopes D, C^{13}, C^{14}, O^{18}, Cl^{36}, Ra^{226} and U^{234}, and detailed chemistry. The wells sampled were selected on hydrogeological criteria by Habermehl and usually located along flowlines of the artesian groundwater in the main Jurassic/Early Cretaceous aquifers, in a pattern radiating outwards from the recharge areas.

During 1974 and 1975 Dr G.E. Calf (AAEC) collected samples from 82 flowing and non-flowing artesian wells in the northeastern, east-central, and south-central parts of the basin. During 1976 a joint party (Calf and Smith, AAEC; Habermehl, BMR) sampled 24 flowing artesian water wells and mound springs in the southwestern part of the basin, and during 1978 a combined party (Calf and Seatonberry, AAEC; Habermehl, BMR) sampled 30 flowing artesian water wells in the southeastern part of the basin. Sampling by a joint party (Calf and Smith, AAEC; Habermehl, BMR) during 1979 was carried out in the northwestern part of the basin. Twenty-six flowing artesian water wells on ten 1:250 000 map sheets in the area Betoota-Birdsville-Bedowie-Boulia-Julia Creek were sampled for environmental isotopes and detailed chemical analysis.

Results from analysis of samples collected in the eastern areas of the basin show that the artesian water is of meteoric origin. Analysis of hydrogeological, hydrochemical, and isotope ratios show that highly compatible results are obtained. Groundwater movements in the main aquifer in the Lower Cretaceous/Jurassic sequence have average velocities ranging from about 1 to 5 m/year. Chloride, sodium, and bicarbonate ions, when plotted against age, all show similar regular curves. A general correlation exist between chloride levels and mean annual rainfall during the last 120 000 years. Some interpretations of early results were published in a joint AAEC-BMR paper, 'Aspects of the isotope hydrology of the Great Artesian Basin, Australia', by Airey & others during 1979.

WIRE-LINE LOGGING OF WATER WELLS IN THE GREAT ARTESIAN BASIN by M.A. Habermehl

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

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

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

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

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

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

Master copies of paper prints of all BMR logs at 1 inch to 100 feet scale were maintained, as well as the original transparencies of the logs which are used to produce copies of logs requested by visitors, industry, and State authorities.

Documentation of a listing of the well and log data commenced.

MURRAY BASIN

by

C.M. Brown

STAFF: C.M. Brown, D.E. Johnstone

INTRODUCTION

The objectives of the Murray Basin hydrogeological project are to collect, analyse, and interpret geological and hydrogeological data, with a major aim of developing and applying a model which, if feasible, can be used to simulate the groundwater-hydrodynamics of the Murray Basin as an aid to the management of its groundwater resources.

Following preliminary discussions, in September 1978, between officers of BMR and representatives of the Geological Surveys and Water Authorities of New South Wales, Victoria, and South Australia, a meeting of interested parties was convened in May 1979 to discuss a project proposal prepared by BMR. It was agreed that the project be expanded to include a review of resources other than water and that a steering committee be established with responsibility for overall coordination. The first meeting of the steering committee was held in Canberra in July 1979 to discuss current work programs. It was agreed that progress reports be issued quarterly and that a general statement describing the project be prepared. The following statement was subsequently endorsed by the participating organisations.

GENERAL STATEMENT

The Murray Basin Hydrogeological Project is a long-term study which is being undertaken jointly by South Australian, Victorian, and New South Wales geological surveys and water authorities and by the Commonwealth Bureau of Mineral Resources, Geology and Geophysics. It will be co-ordinated by a Steering Committee comprising members of those organisations.

The Murray Basin is a geological structure with an areal extent of some 300 000 km^2. In each of the three States the basin sediments contain very large groundwater resources. Where the groundwater has a low salinity it is increasingly being used for irrigation and town water supply purposes. In much of the basin, the groundwater is suitable only for stock use and is extensively used for this purpose. In other parts of the basin the groundwater is too saline for any use. There is a complex interaction between groundwater and surface water which may be either beneficial, as in recharge areas in some parts of the basin, or harmful as in areas of saline groundwater discharge to rivers. In recent years, the States involved have stepped up the rate of assessment of the groundwater regime in the basin.

The primary aim of the Project is to improve the understanding of the groundwater regime of the basin by examining it as a single entity unencumbered by State boundaries. Since a knowledge of the geology of an area is basic to the understanding of groundwater occurrence, a geological study of the basin is an essential part of the Project and as a consequence it will also be possible to make an assessment of other mineral resources.

The project is planned initially to last five years and will be organised in five phases:

(1) Geological synthesis, using all available geological and geophysical data.

(2) Hydrogeological assessment, on the basis of available data.

(3) Documentation of deficiencies in geological and hydrogeological information and formulation of proposals for appropriate work programs.

(4) Additional work as approved which could include stratigraphic drilling, aquifer testing, biostratigraphic analysis, and isotope hydrology studies.

(5) Development of numerical model(s), if found to be appropriate in the light of the data then available.

Investigations currently being undertaken by State authorities will continue, and data generated by them will be used for the joint Basin Project. Collection, collation, and compilation of data during the first phase, and interpretation and documentation of the second and third phases, will be undertaken by officers of BMR with assistance from officers of the State authorities. Additional work required in Phase 4 (e.g. stratigraphic drilling, geophysical investigations) may be conducted by BMR, or by appropriate State authorities. The development of a numerical model (Phase 5) if found to be feasible will be undertaken by BMR. The Project will depend on the close co-operation of staff from all organisations involved, and some movement of staff between organisations for short periods will be necessary. Throughout the study, individuals and organisations will be encouraged to publish results of various aspects of the work. Results of the overall Project will be incorporated into joint publications.

PROGRESS

Preliminary work on the Murray Basin Project has mainly been concerned with data acquisition and with an assessment of the availability and form of geological data which could be contributed to Phase 1 of the project by participating organisations. C.M. Brown and D.E. Johnstone visited Sydney in July, and Shepparton, Melbourne and Adelaide in September, and discussions were held with counterpart geologists on the availability of existing structure contour and isopach maps, bore locality maps, basic borehole data, petroleum and mineral exploration borehole data, geology of pre-Tertiary infrabasins, biostratigraphy, stratigraphic problems, geophysics, and use of Landsat.

In BMR, work commenced on the following -- (i) compilation of a 1:1 000 000-scale geologic map; (ii) plotting of bore hole localities preparatory to compilation of structure contour and isopach maps depicting the Cainozoic geology; (iii) compilation of existing geophysical data; (iv) compilation of existing hydrocarbon exploration data.

MURRAY BASIN BIBLIOGRAPHY

When the Murray Basin Project was first envisaged it was recognised that the lack of a common BMR data base would create problems and delays in the identification and acquisition of the large volume of published and unpublished data on the geology of the basin. It was therefore decided that a bibliographic data base would be established using the Geodx data base designed by C. Watt using the IMAGE 1000 data base management system for use on the BMR Hewlett

Packard computer. Compilation of references involved extensive library research in the BMR library supplemented by visits to State Geological Survey libraries and archives. The bibliography was initially compiled on a card index system (currently 800 references) and information subsequently transferred to the ADP system. Information can be edited and retrieved by year, author, State, basin/ province, or combinations of a wide range of keywords, and the data base provides for the addition of such further information as map reference and stratigraphic nomenclature. The system is compatible with the AMF AESIS bibliographic data base and uses the AMF thesaurus of keywords. It is hoped that the bibliography will enable information to be traced rapidly during the life of the project and that it will be incorporated into a future BMR bibliographic data base.

MICROCOMPUTERS

by

G.E. Seidel

Seidel prepared a feasibility study on the use of microcomputer-based data systems for hydrogeological and geological applications. Programs for data storage, retrieval, and editing with this system were written and tested.

AWRC-TCUW MEETINGS

by

M.A. Habermehl

Habermehl attended a meeting of the Australian Water Resources Council/ Technical Committee on Underground Water Subcommittee on Standards of Presentation of Hydrogeological Data on 23 November 1978 and a meeting of a small working group on 12 December 1978. This group, consisting of M.C. Hind (WRCNSW), M.A. Randal (GSQ), and M.A. Habermehl (BMR), prepared and edited the final report of the above Subcommittee to AWRC-TCUW. Habermehl prepared the section on Hydrogeological Maps.

Following the meeting of AWRC-TCUW in April 1979 Habermehl participated as a member of an AWRC-TCUW Subcommittee for a Proposed TCUW Conference on Groundwater Resource Evaluation, and examined the feasibility of such a conference to be held in 1982.

He also prepared a report on the Hydrogeological Study of the Great Artesian Basin for the 16th Meeting of AWRC-TCUW in Perth in April 1979.

PHOTOGEOLOGY AND REMOTE SENSING

by

C.J. Simpson

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

BMR FIELD RESEARCH

The group carried out photointerpretation of colour air photographs (1:25 000 scale) supplemented by black and white RC9 photos (1:84 000 scale) to assist the McArthur Basin and Georgina Basin Projects.

McArthur Basin Project

Using field data collected in 1978 the geology of the southwestern quadrant of Mallapunyah 1:100 000 sheet was interpreted for drafting.

Georgina Basin Project

The distribution and subdivisions of Proterozoic rocks in the south of the Toko 1:100 000 Sheet area, and in the southwest of the Abudda Lakes 1:100 000 sheet area were interpreted for preliminary map compilation.

In addition, Simpson continued liaison with officers of the CSIRO Minerals Research Laboratories in a combined investigation of hydrothermal phenomena in the Red Heart Dolomite, Hay River area. Fluid inclusion studies show it has been subjected to temperatures of up to 250°C. Nearby thrust-faulting, believed to be related to the Alice Springs Orogeny is considered to have been the most likely source of the heat.

REMOTE SENSING (Landsat)

The group continued their research into Landsat with emphasis on investigating applications of the data to BMR projects.

R.F. Moore (ADP Group) was appointed to continue development of a facility for computer-manipulation of Landsat computer-compatible tape data. The interactive system developed to date has reached the limit of its versatility with the black and white video monitor, and attempts are being made to obtain a colour video system.

During August, Simpson and Perry (Group Supervisor) carried out ground and helicopter spectral radiometer measurements over selected rock, soil, and vegetation targets in the McArthur River region. The information will be used to calibrate Landsat data as part of a research program with the objective of developing computer-assisted techniques to aid in the search for mineralisation and in the discrimination of rock types.

Simpson worked with J.F. Huntington, J. Weishman, and A.A. Green (CSIRO Division of Mineral Physics) on a lineament study of the Pine Creek Geosyncline. Analysis of combined Landsat and aeromagnetic data defined two new representative lineament zones which may be of different ages. Some relationships between mineral occurrences and certain lineaments were also indicated. The results of the study were presented by Simpson at the International Uranium Symposium on the Pine Creek Geosyncline (Sydney 4-8 June).

The Group is participating in the Nuclear Energy Agency/International Atomic Energy Agency sponsored program of Landsat research in uranium provinces and will concentrate on the Pine Creek Geosyncline.

Simpson, Perry, and Moore attended the Landsat '79 Conference (Sydney, 22-25 May). A paper detailing some BMR applications of Landsat was presented by Simpson.

The Group organised a workshop course 'Geological application of Landsat imagery' for the Australian Mineral Foundation for 27 November - 1 December 1978 at the Canberra College of Advanced Education. The course was presented by the Group in association with Dr K.N. O'Sullivan (CRA Exploration Pty Ltd), Drs J.F. Huntington and A.A. Green (CSIRO Division of Mineral Physics), and Mr J.G. Wilson (Hunting Geology and Geophysics (Australia) Pty Ltd).

OTHER ACTIVITIES

The Group continued to provide display and instruction on photogeology and remote sensing. Delegations from China and from Canberra College of Advanced Education visited the group.

Perry (Course Leader) and Simpson in association with J.F. Huntington and J.G. Wilson conducted the course 'Photointerpretation for Survey and Exploration Geologists' for the Australian Mineral Foundation (Adelaide, 15-26 October).

Group members attended meetings of the interim Australian Liaison Committee on Remote Sensing by satellite (ALCORSS), and of the Commonwealth User Committee on Remote Sensing (CUCRS). Perry and Simpson are BMR representatives on CUCRS, and Perry is CUCRS representative on ALCORSS.

In April Simpson was called as an expert witness on airphoto interpretation to give evidence before the Arbitration Hearing investigating flooding at the central Hospital Services complex at Crace.

MARINE GEOLOGY AND COASTAL STUDIES

CO-OPERATIVE PROJECTS WITH FEDERAL REPUBLIC OF GERMANY

by

N.F. Exon

SULU SEA SEDIMENTATION

The results of Exon's 1977 Valdivia cruise with Kiel University in the Sulu Sea were outlined in last year's Summary of Activities. A cruise report was published in the March 1979 issue of the CCOP Newsletter, and a paper entitled 'Morphology, water properties, and pelagic and turbidite sedimentation in the silled Sulu Sea, southeast Asia' was submitted to Marine Geology in June.

EXMOUTH AND WALLABY PLATEAUX GEOLOGICAL CRUISE

In early 1979 Exon, Jones, Shafik, and Colwell of BMR, and three Australian university scientists, took part in a six-week geological cruise aboard the West German research vessel Sonne, in co-operation with the Bundesanstalt fuer Geowissenschaften und Rohstoffe, Hannover. The cruise came under the German-Australian Scientific Agreement.

The main aim of the cruise was to sample pre-Quaternary strata cropping out on the plateau margins; subsidiary aims were to sample the Quaternary sequence on two representative profiles from continental shelf to abyssal plain, to search for manganese nodules, and to obtain Quaternary cores for gas analysis. Generalised ship tracks and sampling areas are shown in Figure S3.

During the cruise 31 single-channel seismic profiles were run to help select sampling targets. On the Exmouth Plateau and adjacent areas 102 stations were successfully occupied, 31 yielding pre-Quaternary rocks. On the Wallaby Plateau and adjacent areas 18 stations were successfully occupied, 13 yielding pre-Quaternary rocks. Samples were obtained from depths ranging from 100 m to 5200 m.

The sampling of pre-Quaternary strata has shed new light on the area. On the northern Exmouth Plateau (Areas B, C, D) thick sequences of Early Jurassic shelf carbonates and Middle Jurassic coal measures were found beneath the main (?Late Jurassic) unconformity. Cretaceous shelf and pelagic sediments were also shown to exist. Above the main unconformity there is a condensed sequence of Cainozoic pelagic carbonates. On the northern margin of the Wombat Plateau (Area D) there is a volcanic sequence at least 300 m thick beneath the main unconformity. On the northwestern Exmouth Plateau (Area E) Albian and Miocene carbonates were sampled. On the southern margin (Areas F, G) results were disappointing, but Mesozoic sandstone, Jurassic shale, and Tertiary pelagic carbonates were sampled.

The layered sequence below the main (?Neocomian) unconformity, both on the eastern Wallaby Plateau and on the 'Sonne Ridge', which extends northward from the plateau into the Cuvier Abyssal Plain, was shown to consist of interbedded weathered 'basalts', tuffs, breccias, and volcaniclastic sediments. This suggests that a thick volcanic pile of Early Cretaceous age forms much of the Wallaby Plateau.

A variety of Quaternary cores, almost all of biogenic carbonates, were obtained on profiles from Rowley Shoals to the Argo Abyssal Plain (Profile A), and from southwest of Barrow Island to the Cuvier Abyssal Plain (Profile F). Quaternary cores in the central Exmouth Plateau were sampled for gas analysis; preliminary results indicate that methane is generally present, but in very small amounts. Manganese nodules were obtained from the southern and eastern margins of the Wallaby Plateau, and determinations of contents of nickel, copper, and cobalt suggest that they are about average for the Indian Ocean and well below a grade of economic interest.

A detailed examination of the sand and silt fractions of the Quaternary cores has been made. Results indicate that the surface sediments are dominated by siliceous organisms (radiolaria with minor diatoms) at depths greater than

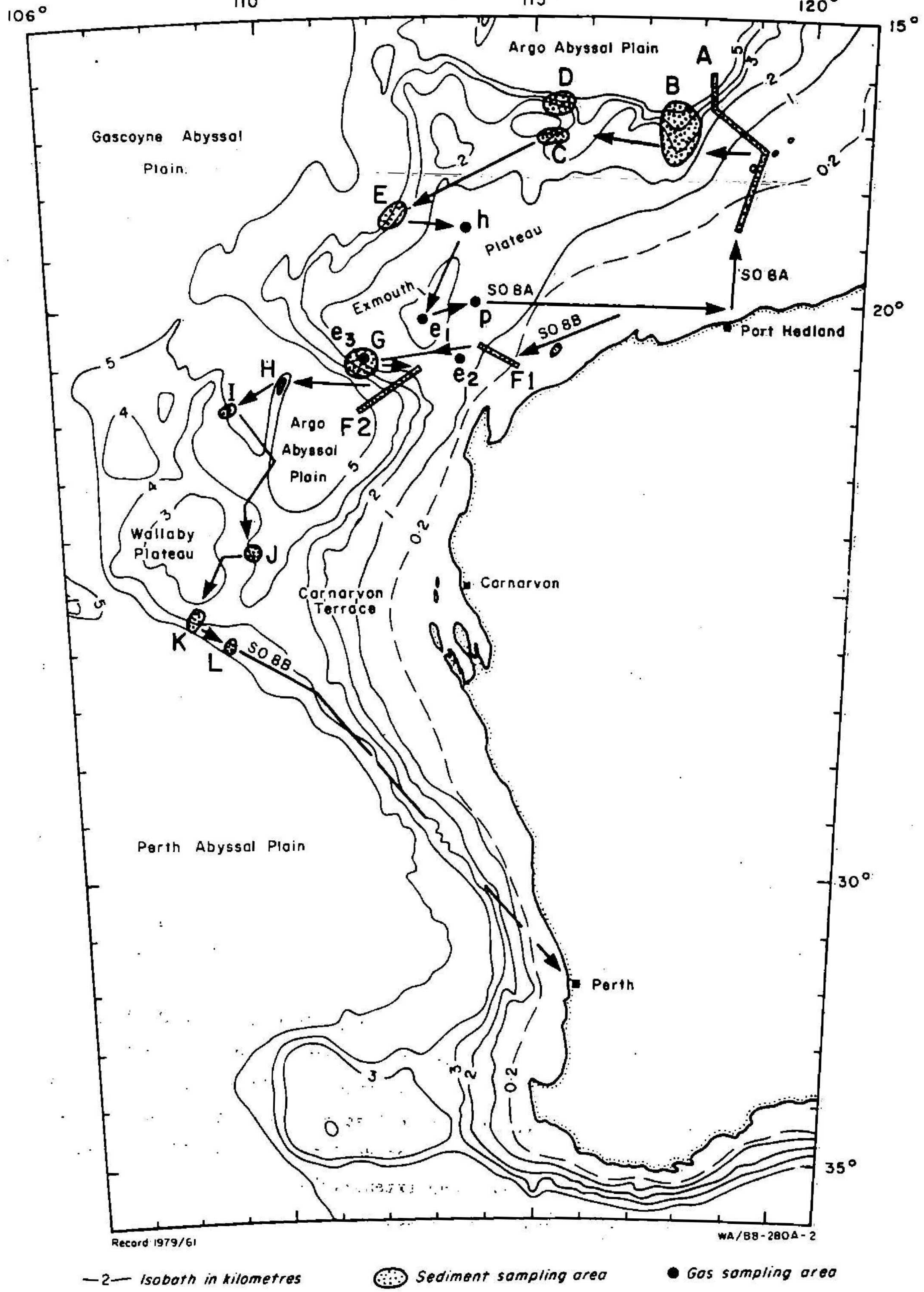

Fig. S3 Cruise tracks Exmouth Plateau

4900 m, by planktonic forams between 4900 and 800 m, and by planktonic forams and pteropod fragments at shallower depths. Variations which occur in the composition of the biogenic fraction with depth in the cores are interpreted as being related to changes in the carbonate compensation depth, the input of material from shallower depths, and selective size sorting related to current action.

Preliminary results of the cruise were reported in Record 79/26, and papers covering various aspects of the results are in various stages of preparation.

GREAT BARRIER REEF STUDIES

by

P.J. Davies

STAFF: P.J. Davies, J.F. Marshall, J.H. Kennard, B. West, D. Foulstone

Drilling operations

Further drilling was carried out with the portable rotary drilling rig built by BMR and first used during the 1978 season. During the 1979 field season, drilling was conducted on windward and leeward reef flats and on a lagoonal patch reef during low tide. A total of 16 holes have now been drilled with this equipment and recovery has ranged from 50 to 95 percent.

Holocene reef structure and lithification

Marked differences in structure have been observed in boreholes drilled on the windward and leeward parts of Holocene reefs. The windward margin cores are typified by the development of massive coral heads and thick crusts of coralline algae which form a very solid framework. Branching corals that form a more open framework are typical of leeward margin cores. Drilling and vibrocoring have shown that unconsolidated sediments, mainly sands, are present beneath a large section of the windward reef flat and beneath the prograding sand wedge. A patch reef drilled at One Tree Reef shows development of massive corals and coralline algae that have been extensively bored and infilled by both lithified and unlithified internal sediments.

Marine lithification processes involve the development of crystalline aragonite and high-Mg calcite cements and microcrystalline cementation of internal sediments. Aragonite cements are exclusively intraparticle, usually forming within the chambers of corals and growing syntaxially from the coral wall. High-Mg calcite cement forms isopachous rims either lining the walls of corals or coating and cementing grains. Peloidal micrite, consisting of spherical or subspherical bodies of microcrystalline carbonate, is commonly present within intra- and interparticle voids. Commonly the peloids have fringes of a more crystalline high-Mg calcite cement. Internal sediments consisting of silt- or very fine sand-size particles, particularly sponge chips, and micro- or submicrocrystalline carbonate are commonly lithified, indicating precipitation of microcrystalline carbonate cement within these sediments. The volume of internal sediments is greatest within the boreholes from windward margins and from the patch reef at One Tree Lagoon.

Reef growth rates

The rates at which coral reefs accumulate $CaCO_3$ have long been a subject of speculation. Data bearing on the subject have been obtained by stratigraphic and chemical methods.

Stratigraphic drilling in the Great Barrier Reef has shown that throughout the Holocene, vertical growth rates have ranged from as little as 0.2 mm $year^{-1}$ to as much as 6.0 mm $year^{-1}$. This growth rate range is attributable to the time at which a reef comes under the influence of the surface hydrologic regime, and to the environment encountered within a drill hole. The drill hole data, however, serve to identify three distinct growth periods: an early, little understood slow growth phase, a period of accelerated growth when the reef had established itself and was accreting most if not all that it produced, and a period of decreasing growth after the reef had built itself up to within a few metres of stabilised sea level.

Chemical measurements of modern growth rates in different reef environments also indicate variations between 0.2 - 6.0 mm $year^{-1}$.

Agreement between the two sets of data implies that the range of calcification rates has changed little throughout the Holocene. There appears, however, to be both a maximum rate attained (presumably under the most favourable conditions) and lesser rates characteristic of particular environments.

The data also suggest that the overall rate of reef growth lags behind the rate of sea-level rise.

Many reefs of the Capricorn/Bunker Group are characterised by prograding sand sheets, the major sedimentological process of lagoon infill. Traction-carpet sampling and coring across the sand sheets show a decrease of grain size with depth. Horizontal growth of the nose of the sand sheet is approximately 40 m/10^3 years while the top surface is being slowly deflated, probably by bioturbation and wave transport.

Sediment transport studies

Quantitative estimates of the movement of suspended sediment through modern reef systems were obtained during the 1979 field season in the Southern Great Barrier Reef. Two new instruments were developed to do this job, (1) suspended load samplers, and (2) current data loggers. These are briefly described below.

Suspended load samplers

Plastic sample containers (2-litre and 4-litre) mounted at different heights on an aluminium tower 3 m high which is fixed to the substrate by steel guy ropes. Combinations of a syphon action and ball-floats allow suspended sediment to be sampled during a rising and falling tide. The samples are collected at low tide, and the particulate calcium carbonate determined by titration.

Current data loggers

A 16-channel data logger was constructed and packaged in the BMR Electrical Engineering workshop. Electromechanical current sensors are linked to the data logger which is programmed to sample water velocity at predetermined intervals. Data are stored on magnetic tape and processed in the field laboratory. Thirteen experiments varying in time from over 1 to 6 tidal cycles were completed at One Tree Reef.

Preliminary results

On the windward margin, suspended load over a tidal cycle averages 1.0 gm^{-3} of water, and this is transported from windward to leeward at velocities varying from 10-30 cm sec^{-1}. On the leeward margin, suspended load averages 1.5 $g.m^{-3}$, but water movement is towards the lagoon on the rising tide and oceanwards on the falling tide. Much suspended load sediment therefore leaves the reef over the leeward margin. Lagoonal infill is dependent upon the state of the tides, most sedimentation occurring during neap tide periods.

SCOTT PLATEAU GEOLOGY

by

N.F. Exon, H.M.J. Stagg

A Bulletin, 'The geology of the Scott Plateau off northwestern Australia', was completed, and is now with the editors. A short note entitled 'The Scott Plateau off Western Australia: data supporting a continental origin' was published in the Journal of the Geological Society of America. The details of the geology of the plateau are discussed in more detail in the Geophysical Branch Summary of Activities.

MANGANESE NODULES FROM THE TASMAN SEA

by

N.F. Exon

During a short geological cruise by HMAS Kimbla five stations were occupied in deep water in the southern Tasman Sea. Reddish brown clay, but no manganese nodules, was recovered from three stations in water depths of about 5000 m, north of where R.V. Galathea had dredged manganese crusts in 1951. Two nodules were, however, recovered from a station in a water depth of 4300 m well to the northwest of the Galathea station and about 40 nautical miles northwest of Gascoyne Seamount. They were associated with greenish grey calcareous mud laid down below the lysocline but above the carbonate compensation depths. The nodules are subspherical, about 10 cm in diameter, and have a high clay content and low contents of Ni, Cu, and Co. The results were reported in Record 79/62, and in a short note in press in the BMR Journal.

MORPHOLOGY AND STRUCTURE OF WESTERN BASS STRAIT AND THE WEST TASMANIAN SHELF

by

H.A. Jones

The shallow seismic reflection profiles in west Tasmanian waters collected during the 1973 reconnaissance survey by BMR have been examined in collaboration with G.R. Holdgate, formerly of the Victorian Geological Survey. The objective of the study is to elucidate the late Cainozoic geological history of the region.

A regional unconformity separates a lower sequence, commonly gently folded and probably consisting of limestones of Miocene age, from an undeformed upper sequence of (?) Pliocene to Holocene age. The upper sequence is absent from the inner shelf off southwestern Tasmania, from the entire shelf south of King Island, and from extensive areas of shallow basement on the highs separating the Bass and Otway Basins. In these areas Miocene or older rocks directly underlie the sea floor, although thin veneers of Holocene sediment may be present locally.

Although the shelf break along the West Tasmanian shelf maintains a fairly constant depth (about 150 m), uplift of the northern part relative to the south is indicated by the extensive erosion of Miocene rocks which has occurred in the north. Rapid deposition of late Cainozoic sediments has allowed upward and outward building of the southwestern Tasmanian shelf to a depth controlled by Plio-Pleistocene eustatic low sea levels.

OFFSHORE HEAVY-MINERAL SANDS

by

J.B. Colwell

A reappraisal was made of the available seismic, bathymetric, and company data of relevance to the search for heavy-mineral deposits on the continental shelf of New South Wales. This work was undertaken with the aim of aiding planning for a cruise proposed for the R.V. Sonne during the latter part of next year, and follows the work of Jones & Davies reported in the 1978 Summary of Activities. The overall conclusions of the earlier interpretations have been confirmed. A series of manuscript maps on 1:150 000 scale consolidating the seismic and bathymetric interpretations were compiled.

PALAEONTOLOGICAL STUDIES

D. BURGER (assistant L. Kraciuk)

Study of Carpentaria Basin palynology

A study of the Jurassic floras was completed. A separate study was made of the Neocomian dinoflagellate and spore/pollen sequence. The marine record has laid the foundation by which non-marine sedimentary formations can now be dated palynologically in the absence of other palaeontological evidence. The Aptian-Lower Albian spore/pollen sequence (Wallumbilla Formation, Toolebuc Formation) was examined, partly with the aim of examining the angiosperm microfossil record.

Surat Basin palynology

Corrected proofs for BMR Bulletin 189 were returned to the Printer in October.

Fifth International Palynological Conference (Cambridge, 1980)
Twenty-fifth International Geological Congress (Paris, 1980).

A paper is being prepared on the most recent data concerning Albian angiosperm evolution in eastern Australia, to be presented in Cambridge. A paper on stratigraphic palynology of the Cretaceous in eastern Australia is being prepared, to be presented in Paris.

Kota Basin Project

Upper Tertiary sediments of the Palembang Basin, Sumatra, were examined palynologically, and preliminary results summarised in Professional Opinion 79.005.

RV Sonne Project

Samples collected from the Scott, Exmouth, and Wallaby Plateaux by the Research Vessel Sonne were tentatively dated Jurassic or Cretaceous on their palynological contents. More detailed information will be published later.

Miscellaneous projects

A paper on the eastern Eromanga basin by Burger & B.R. Senior entitled 'A revision of the sedimentary and palynological history of the northeastern Eromanga Basin, Queensland' was published in the J. Geol. Soc. Aust. 26 (1979), pp. 121-132. Updating of fossils filing systems (punch-card, computer) and curating of slide collections (CPC, ESCAP) are continuing activities.

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

A paper, 'Influence of plate tectonics on the distribution of Late Palaeogene to Early Neogene larger foraminiferids in the Australasian region', was presented at ANZAAS in Auckland during January 1979. This paper is to be published in Palaeogeography, Palaeoclimatology, Palaeoecology vol. 24, 1980.

Whilst in New Zealand, a visit was made to the Palaeontology Section of the New Zealand Geological Survey, Lower Hutt, to examine reference collections of larger and planktic foraminiferids. Following this, several localities in the North Island were visited and collected. Specimens from these collections have been added to the ESCAP Fossil Reference Collection.

The study of larger foraminiferids from the Early Miocene of Victoria continued through the year. Specimens from this work have also been added to the ESCAP Collection. From the studies made so far, it seems obvious that Cyclodypens carpenteri has a very limited stratigraphic range in southeastern Australia. In this region it is confined only to the upper part of the range of Lepidocyclina (Nephrolepidina) howchini. This may be due in part to water depths but as the two species occur together in very shallow depths in rocks of equivalent age in Western Australia, it would seem that temperature was the controlling influence, with Cycloclypens carpenteri tolerating warmer water conditions. Thus, it would seem that the influx of Cycloclypens occurred during the highest water temperatures. Another feature of the faunas of the late Early

Miocene of Victoria, is that the presence of larger foraminiferids definitely indicates new tropical conditions; however, the planktic foraminiferal assemblages are clearly temperate, indicating that the oceanic water temperatures were clearly cooler than those in the shallow waters surrounding the continent.

Palaeontological work for the Irian Jaya Project and the Papua New Guinea Geological Survey continued when necessary. In addition, some material from the Sonne cruise was examined in late February, and cores from drill holes from Niue Island, submitted by G. Jacobson were also examined. Assistance was also given to Dr Tony Watts of the Lamont-Doherty Geological Observatory for the micropalaeontological examination of a sample from the Central South Pacific Ocean; and to R.V. Burne of the marine group in the identification of Holocene foraminiferids from Spencer Gulf.

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

Editing of Bulletin 184 on Tertiary ground birds of Australia by P. Rich was completed and the volume has been printed and issued. This volume has caused considerable interest and most recently has been referred to in Search (Vol. 10, No. 10, p. 331).

Permian fossils from the Hunter Valley of the Sydney Basin have been studied and a manuscript prepared as part of a joint project with the Geology Department of the University of Newcastle on the structural development of the northern part of the Sydney Basin. Papers are also in press or have been prepared on a moraine in the Permian of the Sydney Basin, tilloids of the Bonaparte Gulf Basin, and the climate of the Late Palaeozoic.

Papers have been refereed on foraminifera, brachiopods, and pelecypods and various internal reports examined and commented on.

The meeting of the Australasian Association of Palaeontologists in Wollongong in February was attended along with other members of the Palaeontological group. An important part of the discussion of the meeting was biostratigraphical nomenclature.

A visit to the USA was undertaken to attend the 9th International Congress on Carboniferous Stratigraphy and Geology. This visit was concerned with organising a symposium on Late Palaeozoic climate. The opportunity was taken of examining collections in the American Museum of Natural History, New

York and the Natural History Museum (Smithsonian Institution), Washington. Late Upper Carboniferous marine faunas are poorly developed in Australia and Western Europe. Examination of the faunas of this age in the United States, which are well developed, has tended to confirm that faunas regarded as Asselian (lowermost Permian) in Australia are post-Pennsylvanian (i.e. post-Carboniferous).

Visitors concerned with Upper Palaeozoic work included C.R. Gonzalez from Argentina (December to May) who was making comparisons of the South American and Australian marine faunas and Professor K.R. Surange and Dr S. Chandra from the Birbal Sahni Institute of Palaeontology, India who were working on plants. Five palaeontologists interested in Lower Palaeozoic fossils from the Academia Sinica, China visited the group in July.

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

The compilation of a monograph on Western Australian trace fossils is under way. The philosophical basis of naming ichnolites is examined, 16 ichnogenera are studied, and some errors in previous publications are corrected. Lectures on fossils were given to local societies and fossil exhibitions arranged.

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

Research continued on Carboniferous and Devonian ostracods, Devonian thelodont scales, and Cambrian bradoriids in order to determine their age and ecological significance as aids for correlation.

A paper was prepared in collaboration with Dr I.G. Sohn (U.S. Geological Survey) entitled 'Carboniferous ostracodes - a biostratigraphic evaluation' for publication in the Compte Rendu of the 9th International Congress on Carboniferous Stratigraphy and Geology. Jones took part in the technical sessions of the Congress in Urbana, Illinois (May 21-26), where this invited paper was delivered at the symposium - 'Zonation of the Carboniferous by microfossils'. He also reported on the taxonomy of certain beyrichiacean ostracods at a more specialised session on 'Carboniferous ostracodes'.

Studies of the Early Carboniferous Ostracoda of Western Australia continued, including the taxonomic revision of a manuscript on the faunas from the Bonaparte Gulf Basin. Further biostratigraphic data on this basin were obtained from a study of subsurface material, supplied by Aquitaine Australia Minerals Pty Co., covering the interval about the Devonian-Carboniferous boundary. The same stratigraphic interval is also being studied in the Canning Basin. This project is integrated with conodont studies conducted on the same material.

Research on Middle Cambrian bradoriids from the Georgina Basin, in collaboration with Dr K.G. McKenzie (Riverina CAE), has dealt with Queensland faunas from the late Templetonian Monastery Creek Phosphorite Member of the Beetle Creek Formation, and the upper (Undillan) part of the Current Bush Limestone. A manuscript has been prepared which describes the bradoriids from these rocks and discusses the palaeobiogeography and possible biological affinities of the Bradoriida. A preliminary note on traces of thoracic segmentation is a new genus of Undillan age has been submitted to Search.

Revisions to a paper in preparation describing Devonian thelodont scales from the Toko Syncline, Georgina Basin were discussed with co-author Dr Susan Turner (Hancock Museum, University of Newcastle-upon-Tyne, UK) during her visit to Canberra (May 9-11)

A study (Prof. P. Tasch, University of Wichita - senior author) of conchostracan faunas from the Canning Basin (Carboniferous, Lower Triassic), Bonaparte Gulf Basin (Lower Triassic), and Bowen Basin (Upper Permian, Lower Triassic) has been published - BMR Bulletin 185.

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

Studies of conodont colour alteration, and the interpretation of the level of organic maturity, have been undertaken in specimens from the Canning, Bonaparte Gulf, and Georgina Basins. Conodonts with CAI values as high as 4 have been found at depth in the Canning Basin and in near-surface samples in the Bonaparte Gulf Basin. In the Canning and Georgina Basins the studies were in relation to petroleum prospects. The Bonaparte Gulf Basin samples indicate anomalously high temperatures (200-300°C) that may be related to lead-zinc mineralisation from hydrothermal solutions.

Writing up of the results of the study of Upper Devonian conodont faunas from the Oscar and Napier Ranges, Canning Basin has begun. Several multi-element taxa have been isolated and one of these, Apatognathus, has been written up for outside publication.

The study of Silurian conodont faunas from the Tasman Geosyncline has continued with samples provided by the Araluen and Canberra 1:100 000 mapping projects; the faunas have generally been small in number of specimens and taxa present.

A small Middle Ordovician conodont fauna from the Pittman Formation, Black Mountain (Canberra) has been studied and a report prepared for publication.

M. PLANE (assistant R.W. Brown)

The study of Cainozoic mammalian fossils continued. The correlation of non-marine Tertiary rocks is the primary objective of this work and this is accomplished by estimating the age ranges and environmental parameters of assemblages of taxa. The faunas under study are from Bullock Creek and Kangaroo Well in the Northern Territory, Riversleigh, Queensland, and Lakes Palankarrina, Pitikanta, Kanunka, Tarkarooloo, Namba, and Pinpa in South Australia.

A combined BMR, National Museum of Victoria, Monash University, and South Australian Museum field party worked to the east of Lakes Frome and Eyre. Some heavy equipment, loaned from the ANU, was used at Lakes Pinpa, Namba and Tarkarooloo. This facilitated the removal of overburden and allowed much more efficient use to be made of the time available. Sedimentologists from Monash and the S.A. Mines Department are now involved in these projects and are assisting with interpretations of palaeo-environment. At Lake Palankarinna 5 tonnes of matrix from the White Sands Basin site was collected for processing in Melbourne and Canberra. Work at Mammelon Hill proved disappointing.

Acid preparation of material from Queensland and the Northern Territory is progressing well but slowly. Several new taxa have been recovered.

Fossil mammals from an archaeological excavation in the New Guinea highlands have been examined. A species of Protemnodon, a wallaby-like animal, previously known from the Tertiary of New Guinea and the Tertiary and Pleistocene of Australia, was found and is probably of Pleistocene age - radiocarbon dating is being done.

A chapter on the fossil mammals of New Guinea is being prepared for the book 'Biogeography and Ecology of New Guinea' edited by J. Linsley Gressit of the Bishop Museum, Honolulu.

Technical editing of Bulletin 184, The Dromornithidae was completed and that volume on the giant extinct ground birds of Australia has been published.

A period study of the Oligocene epoch was commenced and data on the Murray Basin are being compiled on data coding forms which had to be designed initially by participants in the study.

There was a considerable amount of input into the siting and planning of the new palaeontological depository which is to be built at Fyshwick.

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

Calcareous nannofossil biostratigraphic studies of the Upper Cretaceous and Cainozoic of Australia and surrounding areas, have continued.

With a high-powered optical microscope on board the R.V. Sonne during her eighth leg (Eastern Indian Ocean), immediate age-determinations were successfully achieved by means of nannofossils. Sediments encountered range in age from late Albian to Holocene.

Although in several instances the recovery was virtually nil (core barrel empty, and only traces of sediments adhering to the core catcher), a few milligrams of the sediments were enough to determine the age and palaeo-environment of the sediments with which the core assembly came into contact. This is possible by means of nannofossils because of the very small size and the usual great abundance of these fossils. Thus, abundant nannofossils, dominated by Discoaster multiradiatus, suggesting warm marine environments during the late Paleocene, were identified from traces of sediments recovered from the Wallaby Plateau.

It became evident that in wide areas in the Eastern Indian Ocean Quaternary sediments are separated from older sediments by a disconformity of variable magnitude, and that a late Oligocene/early Miocene disconformity occurs in the northern part of the Exmouth Plateau. Thus, in a 4 m-core recovered from the Exmouth Plateau, a mid-Oligocene section - containing nannofossils characteristic of the Sphenolithus distentus Zone - is directly overlain by assemblages assignable to the late Miocene Ceratolithus primus Subzone, which in turn is overlain by Quaternary sediments dominated by abundant Gephyrocapsa spp.

Study of the Upper Cretaceous sediments of the onshore Perth Basin was completed. With the recognition of the Marthasterites furcatus and Broinsonia parca Zones (bracketing the Lucianorhabdus maleformis Zone), this study identified fully marine Coniacian and Campanian phases in the Gingin Chalk that were hitherto unknown. A firm correlation is now established between the Lancelin Beds and the Campanian part of the Gingin Chalk, based on the striking similarity of their calcareous nannofossils. This may, however, suggest that the name Lancelin Beds is a junior synonym of the name Gingin Chalk - a problem which can only be solved by drilling in the Lancelin area.

The study of the onshore Upper Cretaceous of the Perth Basin supplements earlier work by Shafik in the Basin; a substantially complete picture of the Upper Cretaceous and Lower Tertiary nannofossil biostratigraphy and palaeoenvironment of the Perth Basin is now emerging.

A short paper on the validation of Chiastozygus fessus and Reinhardtites biperforatus - two prominent members of the nannofossil assemblages of the Gingin Chalk, Perth Basin - is in press in the proceedings of the International Nannoplankton Association

Based on core material from Lynedoch No. 1 Well, a study of the offshore stratigraphic sequence of the Northern Territory was also completed (Professional Opinion 79.029). Based on known stratigraphic ranges of several key nannofossil taxa, the age of the greater part of the sequence is Early Cretaceous to mid-Tertiary (probably middle Miocene). The sequence includes dateable nannofossil assemblages alternating with intervals which are either barren or contain sparse, long-ranging and poorly-preserved nannofossils. Rates of accumulation of the intervals with dateable assemblages are high, but average rate of accumulation of the entire sequence is relatively low. This is taken to suggest frequent occurrence of breaks in sedimentation within the sequence. Where nannofossils are present in the sequence, they contain elements suggestive of shallow-water sedimentation.

A sample collected from the flanks of the Louisville Seamount (during the R.V. Vema cruise 36-02), SW Pacific - critical to the origin of this seamount - was found to contain a cold-water nannofossil assemblage indicative of late Oligocene age (Professional Opinion 79.023).

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

S.K. Skwarko continued work on the Mesozoic marine macrofossils of Australia and Papua New Guinea. He also identified and dated 60 collections of fossils from Irian Jaya and Papua New Guinea - mainly of Triassic and

Jurassic age. He continued the updating of the computerised palaeontological bibliographic references retrieval system and introduced the same system to the Palaeontology Laboratory, Geological Research & Development Centre, Bandung, Indonesia.

Later in the year Skwarko became directly involved in the palaeontology of Indonesia within the framework of the Irian Jaya Geological Mapping Project under the auspices of a Colombo Aid Scheme. He spent five weeks in Bandung and two weeks in Irian Jaya. In Bandung Skwarko helped establish a Macropalaeontological Research Group at the Laboratory of Palaeontology of the Geological Research and Development Centre. The group has office and laboratory space and facilities for four palaeontologists (Palaeozoic, Mesozoic, and hopefully Tertiary macrofossils) and four technical staff, and, though at the moment seriously understaffed, should be ready to process the first fossils from Irian Jaya before the end of the year. The purpose of Skwarko's visit and future visits to Irian Jaya is to collect fossils and give professional opinions on fossils collected in the course of regional geological mapping, as well as to continue training Indonesian staff in palaeontological techniques.

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

Strusz is engaged in a stratigraphic and palaeontological study of Ordovician to Devonian rocks in southeastern Australia, particularly around Canberra. This study is a contribution to the understanding of the tectonic and metallogenic evolution of the Lachlan Fold Belt, and, internationally, a contribution to Project Ecostratigraphy (IGCP, Category A).

The stratigraphic aspects of this study at present involve supervision of the 1:100 000 mapping by R. Abell (Canberra sheet) and M. Owen and D. Wyborn (Araluen sheet).

Palaeontological studies are designed to provide a biostratigraphic framework in an area of great need: Silurian shelly faunas, many of whose Australian representatives are either still undescribed or have not been revised in the light of modern systematic work. The first project in this field was a revision of the trilobites of the family Encrinuridae, a group widespread both in Australia and the rest of the world, and much in need of revision. A paper on the results was submitted to Palaeontographica at the end of 1978.

Consideration of likely return for effort, and of the availability of suitable stratigraphy controlled material, has led to an extended study of brachiopod faunas. A large and excellently preserved fauna of Wenlockian age, from just west of Canberra, is being written up. The trilobites in the fauna have already been done, either as part of the encrinurid study or by Chatterton & Campbell, and, together with the 21 brachiopod species (mostly new), will comprise the first well-documented fauna of that age in southeastern Australia.

Another contribution to local Silurian stratigraphy has been the collecting of the Llandoverian graptolite Monograptus exiguus from a temporary exposure of shale on Camp Hill, lying unconformably beneath Camp Hill Sandstone, thus establishing the relative positions of that unit and the State Circle Shale, and also fixing the age of the unconformity exposed in State Circle and on Capital Hill as early Wenlock.

Further activities during the year were:

1) Editing and marking-up Bulletin 186, on Cambrian trilobites from the Chatsworth Limestone (by J.H. Shergold);
2) Curatorial work on Silurian shelly-fossil collections.
3) Identification and listing of A.A. Opik's Canberra fossil localities, from information supplied by him.
4) Australian correspondent for Fossil Cnidaria, newsletter of the International Research Group on Fossil Corals and Coral Reefs.

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

E.M. Truswell returned from a year's leave in late March, 1979. For the remainder of the year her research can be classified into three major areas: the palynology of offshore Antarctic sediments, Cainozoic palynology of Australia, and Permo-Carboniferous palynological biostratigraphy of Australia.

Sediments immediately offshore from the Antarctic continent are frequently rich in pollen and spores that have been recycled from older deposits on that continent by glacial action. Plotting the distribution of pollen of different geological ages in this offshore area can frequently yield useful clues to the sedimentary geology beneath the ice-cover. These data provide a useful supplement to geophysical studies, such as radio-echo soundings, which yield information on the possible configuration of sedimentary basins. To this end, over 100 samples of bottom muds from regions off Wilkes Land and in the Ross Sea have been macerated for their spore and pollen content, which is being examined. Preliminary results from this have suggested the presence of hitherto undetected sequences of Mesozoic and Tertiary age for the area between Prydz Bay and the Shackleton Ice Shelf, East Antarctica: bottom samples from that area are rich in pollen of Permian, Jurassic/Cretaceous, and Early Tertiary ages. Preliminary results of this survey are to be presented at the Geological Society Convention in Hobart in 1980, and more detailed analyses at the 26th International Geological Congress in Paris in 1980. Abstracts have been submitted and accepted for both meetings. An account of Tertiary climatic evolution in Antarctica was presented at the Workshop on Antarctic Geology held in Melbourne in May 1979; an abstract of this paper is in press in the Journal of the Geological Society of Australia.

Some progress was made during 1979 on the study of Cainozoic palynology of inland Australia. Samples from drilling in the Tertiary basins of the southern Northern Territory, by the Northern Territory Mines Department and by BMR have been processed and are being examined. Plant macrofossil assemblages from near Glen Helen are also being examined; a suite identifiable broadly with the '*Cinnamonum*' flora has been photographed.

A manuscript dealing with Tertiary pollen from Napperby, Kiandra, and Cadia in New South Wales is being readied for publication, in conjunction with Dr. J.A. Owen. Core samples from three stratigraphic holes drilled by BMR on the Lake George flats of the Canberra Sheet area have been examined palynologically: all sites have yielded Quaternary pollen - evidence for Tertiary suites is lacking at this stage of the examination. Still in the Cainozoic, material from the Karawari River area of Papua New Guinea has been examined at the request of the PNG Survey, and found to contain altered Tertiary pollen.

In Permo-Carboniferous palynology, some time during 1979 was devoted to the preparation of an article reviewing recent developments in the palynology of the Permo-Carboniferous of Gondwanaland. This review was invited for the 5th International Gondwana Symposium, scheduled for Wellington, New Zealand in February 1980.

A review of a more general nature was prepared during June and July of 1979. This paper, entitled 'Pre-Cenozoic palynology and continental movements' reviews the contributions made by palynology to plate tectonics in the decade 1970-80, and is a contribution towards the final report for Working Group 10 of the International Commission for Geodynamics.

Other activities during 1979 have included participation in the annual meeting of the Australasian Association of Palaeontologists, held in Wollongong in March, 1979; a paper entitled 'Permo-Carboniferous biostratigraphy; a palynological viewpoint' was presented there. As a member of the organising committee for the Historical Botany section of the International Botanical Congress to be held in Sydney in 1981, Truswell attended a meeting of the program co-ordinating committee in Sydney in August, and contributed to the design of the section program. Some organisational work has also been done towards the setting up of a symposium on the Cainozoic evolution of South-eastern Australia, to be held in Canberra in November 1980.

M.R. WALTER (assistant P.W. Davis)

A joint project with Dr I.N. Krylov of the Geological Institute, Academy of Science, Moscow, on the Adelaidean stromatolites of the Amadeus and Georgina Basins was commenced during the winter of 1977 and was completed and published this year. The results support a previous lithological correlation between the Yackah Beds and the Bitter Springs Formation, and several new taxa were described from the Boord Formation, Bitter Springs Formation, Pioneer Sandstone, and Julie Formation of the Amadeus Basin.

Dr. Krylov returned in 1978 and work was concentrated on Carpentarian stromatolites from the McArthur Basin and Isa Geosyncline. New taxa were described from many units (in a cooperative study with Walter and M.D. Muir). Several are distinctive forms which can be compared with previously described pre-Riphean and Early Riphean forms from the USSR. The results of this work tend to support the use of stromatolites for biostratigraphy. In addition, distinctive forms occurring in the Balbirini Dolomite, Emmerugga Dolomite, and Amelia Dolomite have been shown to be useful for intrabasinal correlation.

In an attempt to overcome some of the problems of stromatolite taxonomy, Krylov's concept of bioherm series was applied to complex forms from the Balbirini Dolomite and the Bitter Springs Formation, and was shown to be useful. A bibliography of stromatolite research was prepared and published (in cooperation with Prof. S.M. Awramik, University of California, Prof. J.H. Hofmann, University of Montreal, and A. Haupt).

A study of the microfossil Frutexites microstroma, a scytonematacean cyanobacterium, from the Gunflint Iron Formation was completed and published (in cooperation with S.M. Awramik).

Additional activities are recorded under the Georgina Basin Project.

In June Walter joined the Precambrian Paleobiology Research Group at the Department of Earth and Space Sciences, Los Angeles, California for 15 months. The 14-member team of geologists, chemists, and palaeontologists are studying early Precambrian life and the evolution of the atmosphere.

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

The study of Palaeozoic early vertebrate remains progressed with the addition of new material to the collection, the preparation of previously collected material, and the publication of systematic accounts of various faunas. This research is directed toward the establishment of biostratigraphic zones, based on vertebrates, as an aid in dating and correlation, particularly in non-marine sediments where other fossil groups are often absent. Such sediments are commonly associated with major unconformities, and their accurate correlation is essential to a proper understanding of the geological history of an area. In Australia non-marine sediments of Devonian age are particularly widespread, and six zones based on vertebrate assemblages have now been proposed as subdivisions of Middle/Late Devonian time (see below).

The major study completed during the year was the systematic palaeontology of a new vertebrate fauna from the Hatchery Creek Conglomerate near Wee Jasper, NSW, discovered by the Tantangara Field Party in 1975. The fauna includes thelodont scales, new species of placoderms and crossopterygians, and acanthodian spines and scales. (It indicates that much of the Hatchery Creek Conglomerate (previously regarded as Late Devonian) was deposited during Middle Devonian time, and that the underlying disconformity was of short duration. Several of the new forms in this fauna represent major groups of vertebrates not previously recorded from Australia). A manuscript (with J.D. Gorter, ex-BMR) has been completed for publication in the BMR Bulletin series, and 299 type specimens from the locality have been placed in the Commonwealth Palaeontological Collection.

Other work related to publications included the revision and updating of a manuscript submitted to Palaeontographica last year; the checking of galley proofs of a paper to appear in the Zoological Journal of the Linnean Society (both on Taemas/Wee Jasper material); the proof-reading of an appendix to a paper on the Boyd Volcanic Complex, Eden, NSW, which appeared in the journal of the Geological Society of Australia; the preparation of a review of a work on Devonian lungfishes from Gogo, Canning Basin, which was published in Alcheringa; and the review of two manuscripts prepared by overseas colleagues.

Development of the collections continued with the preparation and curation of Georgina Basin material collected in 1974 and 1977 (see Georgina Basin project) and material from the NSW south coast donated by the Geology Dept., A.N.U. Further acid digestion was undertaken on material from Taemas, Wee Jasper, and a new locality in the Burdekin Basin, Queensland, discovered by Dr J. Jell (University of Qld.). Several facts of biostratigraphic significance have come out of this work: placoderms (armoured fishes) of the family Ptericathyodidae (previously unknown in Australia) have now been identified in at least three widely separate Middle Devonian localities: the southern Toomba Range in the Georgina Basin, Wee Jasper (in both cases associated with thelodonts), and the Burdekin Basin. In addition the group is probably represented in a sample from near Cobar submitted during the year by C.M. Brown. These occurrences provide a basis for correlation, and using associated faunal elements in the Hatchery Creek fauna, and the Cravens Peak Beds (Georgina Basin), two vertebrate zones for the lower part of the Middle Devonian have been proposed. A younger Middle Devonian (Givetian) assemblage is probably represented in the Bunga Beds on the NSW south coast, and higher horizons on the south coast have permitted a tripartite subdivision of the Upper Devonian. Further systematic work should refine these subdivisions. In addition, the Bunda Beds material contains shark's teeth of the type known as 'diplodont', and characteristic of the freshwater xenacanth sharks, again a group not previously known from the Australian Devonian (stratigraphic range in the Northern Hemisphere Givetian-Triassic). Similar teeth associated with spines and scales occur in the Aztec Siltstone, Victoria Land, Antarctica, and a single shark scale possibly belonging to the same group was identified in a sample from Irian Jaya (associated with thelodont scales). With further systematic study this group should also prove useful in correlation. In support of this work on vertebrate microfossils a start was made curating acid residues from the Upper Devonian/lower Carboniferous sequences in the Canning Basin, in which shark remains are fairly common. Together with residues from eastern Australia this will provide the BMR collections with a suite of microvertebrate assemblages ranging from Early Devonian to Early Carboniferous in age.

With the completion of the Hatchery Creek manuscript, work on the large Antarctic collection was resumed. Systematic study of Bothriolepis from the Aztec Siltstone in Victoria Land is nearing completion, with the recognition of 5 or 6 species in the fauna, only one of which has previously been described. This diversity suggests that Aztec deposition continued for a considerably longer period than previously supposed, and accordingly a detailed investigation of other elements in the faunas has commenced in an attempt to identify assemblage zones associated with the different species. So far the main faunal differences recognised are the presence of thelodont scales only in the lowest beds, a number of different placoderm types associated with the various Bothriolepis species, and marked changes in the form of acanthodian spines and palaeoniscoid scales through the sequence. This work is continuing.

Field work during the year was limited to one day at Wee Jasper where Dr S. Turner (Hancock Museum, University of Newcastle-upon-Tyne) was shown the vertebrate locality in the Hatchery Creek Conglomerate, and two weeks in the Eden/Bermagui area, re-collecting from localities discovered by A.N.U. students in 1978. In addition to samples from Irian Jaya and Cobar mentioned above, vertebrate remains were identified from Silurian limestones in the Braidwood area (M. Owen), Devonian limestones from near Tarago (M. Huleatt, M.Sc. student, Macquarie University), and the Upper Devonian Buttons Beds in the Bonaparte Gulf Basin (R.S. Nicoll). About 500 vertebrate fossils were registered during the year, including five thelodont scale samples from Devonian localities in England and Spitsbergen, kindly donated by Dr S. Turner (Hancock Museum).

PALAEONTOLOGICAL LABORATORIES

During the year 1100 samples were washed for microfossil examination, 750 thin sections prepared, and 230 samples polished. 1300 slides of nannofossils were prepared from 360 samples.

In the acid laboratory, Fyshwick, 1300 samples totalling 5300 kg, were processed for extraction of conodonts, and 700 samples picked for ostracods. The palynological laboratory prepared 710 slides from the 205 samples processed.

Macropalaeontological work included the mechanical and acid preparation of 24 mammal, and 150 fossil fish samples, the making of more than 1200 rubber replicas or plaster casts of fossils, and the picking of 2 tonnes of material for mammal remains.

ESCAP STRATIGRAPHIC ATLAS (IGCP PROJECT 32)

STAFF: D.J. Belford (Co-ordinator: on leave without pay with ESCAP)
H.F. Doutch (Project Leader), V.L. Passmore, C.M. Brown

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

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

None of the material so far sent to ESCAP has yet been published, but some is in press. The contributions on the Carnarvon, Laura, Carpentaria, Karumba, and Sydney Basins have been prepared as BMR Records; the notes on the Carpentaria Basin contain source rock data not included in the ESCAP version. Contributions on the Bonaparte Gulf, Money Shoal, and Arafura Basins were completed during the year, and have also been prepared as Records. A contribution on the Browse Basin is in progress. Further contributions are planned for next year.

Dr Belford completes his tour as co-ordinator at the end of 1979.

COAL STUDIES

PERMIAN COALS OF EASTERN AUSTRALIA

by

D.S. Trail

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

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

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

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

Staff for the project have been recruited by CSIRO and are in the process of being recruited by BMR. CSIRO staff have begun sampling coal seams and assembling a bibliography.

D.S. Trail attended the NSW Institute of Technology coal extension course, and coal-oriented symposia on exploration in New South Wales, the Sydney Basin, and the Surat-Moreton Basin.

Beginning in mid-October 1979 a three-week visit to seven mines in the Bowen Basin will yield representative samples of various types and ages of Permian coal and will serve as a reconnaissance of the stratigraphy of the coal measures.

BMR EARTH SCIENCE ATLAS OF AUSTRALIA: COAL DEPOSITS

by

D.S. Trail

A.T. Wells and G.E. Wilford drew up a comprehensive legend for a proposed 1:10 million Atlas Series map on the geology of Australian coal deposits, showing age, overburden, reserves, and production in both exposed and concealed basins.

SURAT BASIN COALS

by

N.F. Exon

A symposium dealing with the coal deposits of the Surat-Moreton Basin was held in Toowoomba in August. Exon gave the opening address entitled 'The stratigraphy of the Surat Basin, with special reference to coal deposits', which is to be published in Coal Geology. Economic interest is concentrated in the Middle Jurassic Walloon Coal Measures, whose proved reserves exceed 2000 million tonnes, and whose probable reserves are much greater. The coal is sub-bituminous to bituminous high-volatile, and is potentially suitable for liquefaction. Workable seam thicknesses, in open-cut prospects, exceed 10 m in places. The only other known potentially economic coal measures occur in the Upper Jurassic Orallo Formation.

OIL SHALE STUDIES

by

D.L. Gibson

STAFF: D.L. Gibson

Contributions to various publications on oil shale were prepared, a bibliography was started, and samples of oil shale from BMR stratigraphic drill holes were submitted for petrographic study, and for analysis to determine their oil yields, their potential as source rocks for hydrocarbons, and the type of kerogens present.

MULTIDISCIPLINARY PROJECTS

Project Managers: A.R. Jensen, G.E. Wilford

GEORGINA BASIN PROJECT

Compiled by

J.H. Shergold, Project Coordinator

STAFF: J.P. Cull[1,4], D.M. Finlayson[1,4], D. Gibson[4], J. Giddings[1,4], P.L. Harrison[1,4], K.A. Heighway, M. Idnurm[1,4], K.S. Jackson[1,4], P.J. Jones[4], J.M. Kennard (until August 1978), S.P. Mathur[1,4], M.D. Muir[4], R.S. Nicoll[4], B.M. Radke, J.E. Rees[1,4], J.H. Shergold, C.J. Simpson[4], D.H. Tucker[1,4], M.R. Walter[4] (until July 1979), R.G. Warren[4], B.W. Wyatt[1,4], G.C. Young[4], P.E. Balfe[3,4], J.J. Draper[3,4], P.M. Green[3], E.C. Druce[4,5] (Dept Trade & Resources); M.W. Sandstrom[5], P.N. Southgate[5] (ANU, RSES); P. West[5] (ANU SGS until May 1979); P.D. Kruse[5] (Univ. Sydney); R.A. Fortey[4,5] (British Museum); N. Russell[2,4], R.W.T. Wilkins[2,4], J. Wilmshurst[2,4] (CSIRO, Fuel Geoscience Unit).

1. BMR Officer, not a member of Geological Branch
2. CSIRO (Fuel Geoscience Unit) Officer
3. GSQ Officer
4. Part-time only
5. Officer of other organisation as specified

GENERAL

The Georgina Basin Project was initiated in 1974 as a pilot study for multidisciplinary projects in BMR, and was programmed to run for five years. During 1979, the final year of the pilot project, emphasis has been laid on completing the publication of results hitherto gathered during field orientated geological and geophysical activities in the basin. These have laid the framework for a series of more specific studies which have ben proposed for a second phase of research in the basin catalysed by Australia's energy requirements in particular.

Officers from BMR (including Geological, Geophysical, and Petroleum Exploration Branches), Geological Survey of Queensland, CSIRO (Fuel Geoscience Unit), Department of Trade and Resources, Australian National University, Sydney University, and the British Museum (London) have been involved in the Project's activities during 1979. Quaterly statements of research in progress and papers prepared by these officers has been documented in four issues of Georgina Research.

STRATIGRAPHY & SEDIMENTOLOGY
(Figure D1)

A regional reinterpretation of the Adelaidean and Early Cambrian stratigraphy, which included a magnetostratigraphic study of the Wonnadinna Dolomite and the Gnallan-a-gea Arkose (in cooperation with Dr. P. Burek, then of ANU), and a palaeomagnetic comparison of the various glaciogenic units (by M. Idnurm and J. Giddings), was completed. The Adelaidean sequence around the southwestern margin of the basin accumulated in fault-bounded troughs, locally reaching a thickness of possibly as much as 10 km (Toko Trough). In the south, the troughs are oriented NW-SE, seemingly with their NE margins being steeper than their SW margins (i.e. resembling half-grabens). This style of tectonism ceased near the end of the Adelaidean, as Early Cambrian sediments are uniformly spread over the region.

Drilling of the dolomitic black shale sequence at the top of the Yardida Tillite confirmed the lithological correlation with the lower tillite of the Adelaidean of the nearby Amadeus and Ngalia Basins, and revealed the base-metal enrichment typical of this black shale sequence elsewhere (e.g. the Tapley Hill Formation of the Adelaide Geosyncline). Interpretation of the surface mapping and stratigraphic drilling revealed a major break in the record beneath the basal Cambrian Adam Shale: equivalents of the Elkera Formation and upper Central Mount Stuart Formation are missing in the Desert Syncline area (M.R. Walter).

Sedimentation patterns of epeiric carbonate sequences in the Georgina Basin are typified by the Ninmaroo Formation (Upper Cambrian - Lower Ordovician) which comprises ooid, peloid-cryptalgal, flat-pebble conglomerate, and skeletal carbonate lithofacies, terrigenous sandstones, and a late-diagenetic crystalline dolostone lithofacies.

Ninmaroo sedimentation was in a broad, shallow epicontinental sea with normal marine, increasingly saline, and evaporitic conditions. A barrier complex of ooid, peloid, and skeletal sands formed the seaward limit of these environments. Channels through this barrier extended weak tidal effects to the periphery of an extensive non-tidal complex of semi-emergent shoals in a patchwork pattern. Here algal and nonskeletal carbonate sedimentation predominated because of higher salinities that restricted the fauna. Sedimentation was cyclic, indicating repeated shoaling from storms. Sabkhas developed locally on emergent areas of shoals and landward where the complex was transitional with an emergent pavement. Where emergence was prolonged, microkarst resulted from both carbonate and sulphate dissolution.

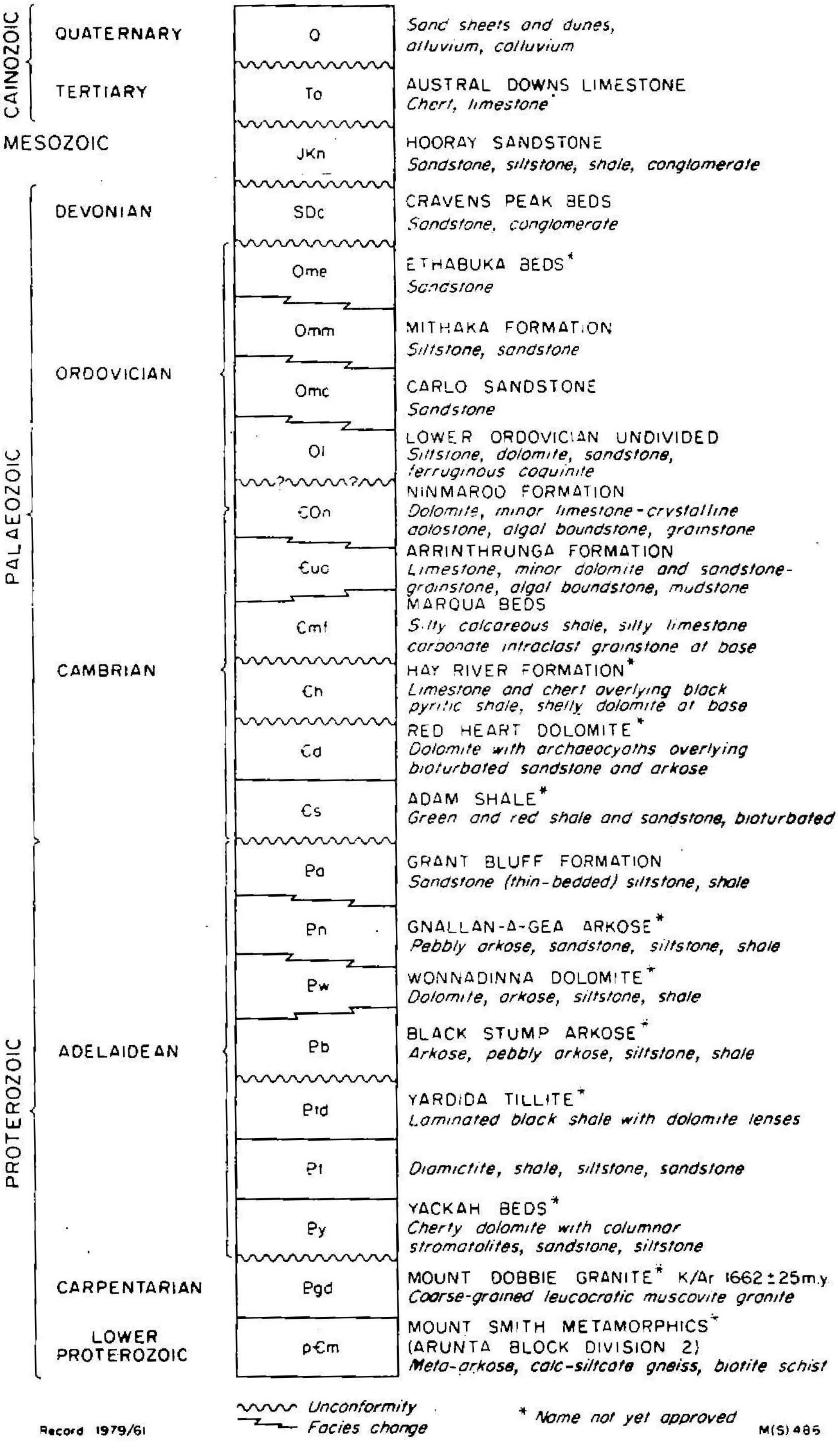

Fig D1 Stratigraphic relationship of formations in the southern Georgina Basin mentioned in this report

Lithofacies patterns indicate two regressive depositional sequences. Initially, the barren and epeiric environments prograded to the SE over a stable and extensive shelf. Subsequent instability increased shelf slope, and telescoped the depositional environments along the margins of the depositional basin. With increased tidal circulation, skeletal carbonate production became dominant, producing the second offlap to the southeast (B.M. Radke).

Earlier, in the Late Cambrian, a similar association of carbonate lithofacies, also exhibiting characteristics of saline and evaporitic conditions, has been recorded in the Arrinthrunga Formation (J.M. Kennard); and in the Middle Cambrian, pseudomorphs after evaporitic minerals have been found at the top of the Thorntonia Limestone (Ardmore Chert Member) (P.N. Southgate), and are widespread amongst the rubble which constitutes the Gum Ridge Formation (J.H. Shergold).

The former presence of sabkha deposits within these units is recognised from textural evidence preserved in carbonates and chert. The primary minerals were dolomite, gypsum, anhydrite, halite, and fluorite. Recognition of the evaporitic sulphates is based on: 1) pseudomorphs or mouldic porosity after crystals and nodules of sulphate; 2) related solution-collapse breccias, buckle-folding in laminates, and emergence features such as desiccation cracks, tepees, calcretes, and microkarst; 3) sediment textures and shapes of carbonate particles that were modified by displacive/replacive sulphate growth before induration. A history of textural modification in host carbonates may be preserved in successively younger growth bands of early-diagenetic cherts. Evaporitic horizons are more abundant in the peloid-cryptalgal and flat-pebble conglomerate carbonate lithofacies, and to a lesser degree in ooid carbonate lithofacies. Cycles within these lithofacies contained sulphate crystals scattered throughout the component lithologies. Anhydrite nodules are more abundant in cryptalgalaminites and finer-grained carbonates. On the regional scale, the condensed sequence over the Smoky Anticline has a greater density of evaporitic horizons than is evident in the Toko Syncline and Burke River Structural Belt.

Following burial and structural deformation, hydrocarbons were introduced with the up-dip migration of basinal brines which produced extensive dolomitisation and minor emplacement of sulphates. Recognition and distinction of this later sulphate overprint is critical to the assessment of evaporite mineral distribution. Distinction is possible from petrographic relationships that indicate timing of emplacement. Where hydrocarbons had already accumulated and occluded porosity, interaction between host carbonates and dolomitising fluids was prevented and bituminous limestones have been preserved. Subsequent faulting produced near-vertical conduits for the escape of deeper and warmer brines which precipitated saddle dolomite, pyrite, fluorite, galena, and sphalerite in the fault zones and along the more permeable strata. Where the sequences had been exhumed by subsequent erosion, relict sulphates have been redissolved and sulphides oxidised in meteoric waters. The interaction of resultant sulphate-enriched waters has produced near-surface dedolomitisation (B.M. Radke).

In contrast to the epeiric carbonates, recent studies of the Georgina Limestone suggest that it is a relatively deep-water facies into which allochthonous materials were deposited. These clasts vary in size and shape, the largest consisting of blocks up to 30 m thick comprising minor algal (*Epiphyton* sp.) boundstone in an oolite-oncolite grainstone. A micrite matrix is present between the blocks. The deposits usually form sheets or channels of various thicknesses. Early lithification features in the form of micrite nodules are common throughout the unit and the micrite plates present in outcrop may have originally been elongated micrite nodules. Ovoid micrite nodules are common in GSQ Mount Whelan 1 where the lithologies were deposited in quiet, deep water with only a rare input of shallow-water material (P.M. Green).

PALAEONTOLOGY

I.N. Krylov (Geological Institute, Moscow) returned to Australia during March and resumed research on Georgina Basin stromatolites. With M.R. Walter, a distinctive columnar branching stromatolite has been described from erratics in the Yardida Tillite which is unlike known stromatolites from surrounding regions that were also studied (M.R. Walter).

An assemblage of organic-walled microfossils has been extracted from Adam Shale in BMR Hay River 11B. It contains numerous filaments plus an assemblage of spheroidal acritarchs which could be assigned an Early Cambrian age (M.D. Muir).

The archaeocyathan fauna which occurs in the upper part of the Mount Baldwin Formation in the Huckitta area is also present in the Red Heart Dolomite in BMR Hay River Nos. 11A and 11B, and in the Todd River Dolomite of the north-eastern Amadeus Basin. The fauna provides an approximate correlation datum for these units, being Atdabanian to early Lenian in age (middle to late Early Cambrian on the Siberian biostratigraphic scale, late Early to early Mid Cambrian on the Australian scale). Several elements of this archaeocyathan fauna are known additionally from the Adelaide 'Geosyncline' (P.D. Kruse).

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A phosphatised shell/tube fauna has also been recovered from the Red Heart Dolomite in BMR Hay River 11B. This fauna contains a tommotiid (aff. Camenella Missarzhevsky), inarticulate brachiopods, Chancelloria sp., an indeterminate hyolithid fragment, and sundry problematical items. Phosphatised residues, from the Monastery Creek Member of the Beetle Creek Formation of the Duchess area have also been examined, and found to contain various bradoriid crustacea, trilobites, various inarticulate brachiopods, molluscs, hyolithids, chancelloriids, miscellaneous forms like Hertzina, the tube Coleoides, and problematica (J.H. Shergold). Some of the bradoriids have been used to advance the knowledge of the functional morphology and taxonomic significance of Bradoriida (P.J. Jones, K.G. McKenzie).

With the completion of palaeontological analysis of the late Cambrian carbonate sequences in the Burke River Structural Belt, a biochronological framework, based on trilobites, is available for this area. Late Cambrian time in such environments in this area is now characterised by twenty assemblage-zones. Since this interval has a duration of 20 m.y., each assemblage has an approximate duration of one million years. Such a fine biochronology permits a more accurate dating of Cambrian events, and the reconstruction of a more detailed palaeogeography (J.H. Shergold).

An early Ordovician conodont biochronology is now proposed for the carbonate sequences (Ninmaroo Formation) of the Burke River Structural Belt and Toko-Toomba Ranges (Coolibah Formation), and for the predominantly clastic sequences of the Toko-Toomba area and Dulcie Range. Seven successive conodont assemblages are recognised in the Ninmaroo Formation of the Burke River area; four are present in the Kelly Creek Formation in the Toomba Range; and three further assemblages occur in the Coolibah Formation, the oldest of which equates with the youngest of the Kelly Creek assemblages. Those conodont faunas permit correlation both with the Baltic lower Ordovician and the platform sequences of North America with some degree of precision (E.C. Druce).

Work on Devonian fish material from the Georgina Basin has been limited mainly to preparation of material collected in 1974 and 1977, with some preliminary study for comparative purposes. However, systematic work on other material from various localities in NSW has proved relevant to the problem of biostratigraphic control in the Georgina Basin Devonian sequence (see Palaeontology section). More detailed study of the Georgina Basin fish material is intended to provide a basis for correlation with similar fossiliferous sequences in other regions (e.g. Canning, Amadeus, Darling and Burdekin Basins, and Lachlan Fold Belt). Acid preparation of limestone material from the southern

Toomba Range has confirmed the presence of a pterichthyodid acritarch in the fauna, associated with other placoderms, crossopterygians, acanthodians, and abundant thelodont scales. There is little doubt that this fauna is older (i.e. Middle Devonian) than the late Devonian antiarchs from the higher fossiliferous horizons in the Dulcie Sandstone. Middle Devonian antiarchs are otherwise known in Australia from the Hatchery Creek Conglomerate at Wee Jasper, NSW, which also contains thelodonts (but a different species or genus), and overlies Emsian limestones. An association of thelodonts and antiarchs has not been reported from any other continent. The limestone horizon in the Toomba Range conformably underlies the sandstones and conglomerates of the Cravens Peak Beds, from which an abundant fauna including the placoderm Wuttagoonaspis is known. On present evidence the same fauna occurs in the Cravens Peak Beds and the basal part of the Dulcie Sandstone. Two, and possibly three, fossiliferous zones occur in the upper part of the Dulcie Sandstone. The presence of the placoderm Phyllolepis was previously regarded as indicating a Famennian age, but recent work on the NSW south coast has shown that, in contrast to its stratigraphic range in the northern hemisphere, this form in Australia occurs in strata at least as old as Frasnian (G.C. Young).

MAPS

Two further preliminary edition 1:100 000 Geological maps, Toko (prepared by BMR) and Mount Whelan (by GSQ), are scheduled to be issued before the end of 1979: both require only final detailing. Abudda Lakes 1:100 000 Sheet is presently being drafted from overlays. Overlays are still being prepared for Mount Barrington (C.J. Simpson, J.H. Shergold).

SEISMIC RESEARCH

The 1977 BMR seismic and gravity survey of the Toko Syncline was intended to investigate the structure of the Toko Syncline and the Toomba Fault which forms its western margin. Results of this survey relating to stratigraphy and petroleum prospects were presented to the 1979 meeting of APEA. Petroleum prospects of this area have been enhanced by the confirmation and definition of the Mirrica-Ethabuka Structure which has a minimum vertical closure of 700 m over a minimum area of 130 km^2, and lies adjacent to the Toomba Fault. Possible stratigraphic traps are located on the northeastern flank of the structure and along the axis of the syncline.

The Toomba Fault and the western margin of the syncline have been studied in detail using reflection and refraction data and gravity modelling on five profiles across the fault. The Toomba Fault was found to be a high-angle reverse fault dipping at between 40° and 70°. Palaeozoic strata to the northeast of the fault are folded into anticlines or monoclines, or are steeply upturned. There is no simple relationship between the Toomba Fault geometry and the deformed strata adjacent to it; this indicates either several periods of movement or local realignment of stress due to basement irregularities. The structural data are consistent with a general northeasterly compression, two stages of deformation being recognised (P.L. Harrison).

A deep crustal survey of the Georgina Basin on a traverse line between Tennant Creek and Mount Isa was commenced in 1979. Two large shots, one at Tennant Creek and the other at Mount Isa were recorded by 41 seismographs along the Barkly Highway. Interpretation of the readings is proceeding (D.M. Finlayson).

GEOCHEMISTRY

A geochemical profile, based on sampling at 1-m intervals, has been established for the Middle Cambrian black shale sequence in Hay River coreholes 11 and 11A. Both the Hay River Formation and the lower Marqua Beds are host to anomalously high base-metal concentrations which are related to disconformities in the sequence. The Hay River Formation is enriched in Cr, Cu, Ni, Zn, V, Mo, Th, U, Sb, Au, and Pd. Two phases of enrichment occur in the lower Marqua Beds which have anomalous Cr, Cu, Zn, V, Mo, and Ba. High Pb values also occur in the Red Heart Dolomite which underlies the black shale in the Hay River coreholes, and anomalous Pb, Zn, and Ba are recorded from equivalents of the Thorntonia Limestone in GSQ Mount Whelan 1. Ba running to 7300 ppm occurs in the lower Georgina Limestone in this hole (J.H. Shergold, K.A. Heighway).

Petroleum source rock studies continued: organic extractive analyses (BMR) and vitrinite reflectance studies (AMDEL, CSIRO, GSQ) have been performed on material from BMR Hay River 10, 11, 11A, and 11B, and GSQ Mount Whelan 1 and 2. Interpretation of these analyses is not yet complete (K.S. Jackson).

Residues of hydrocarbons are present as bituminous interparticle pore infillings in the Ninmaroo Formation of the Toko Range and the Burke River Structural Belt. Assessment of the thermal maturity of this formation is based on a conodont colour alteration index (CAI) and vitrinite reflectance analysis (GSQ). Both approaches indicate a moderate thermal history: CAI determinations suggest palaeotemperature ranges of 60-140°C in the Toomba Fault region, and slightly lower temperatures of 50-90°C at Mount Ninmaroo (Burke River Structural Belt). Vitrinite is extremely scarce in the sequence. Determinations of material from GSQ Mount Whelan 2 indicate vitrinite reflectance values of 0.76 to 0.8%. Extrapolation of this data gives an approximate maximum depth at which liquid hydrocarbons can be expected - 3000 m, assuming 1.3% vitrinite reflectance value indicates the upper limit to the oil window (B.M. Radke, R.S. Nicoll).

However, two lines of evidence suggest that the neighbouring Hay River area (west of the Craigie-Toomba Fault Complex) has undergone a thermal history which has important implications for the discovery of liquid and gaseous hydrocarbons in that area at least. Pyrobitumen (mesophase) has been discovered in Middle Cambrian black shales and filling vugs in the Lower to Middle Cambrian Red Heart Dolomite in the Hay River coreholes. It has also been recognised in equivalent strata in PAP Netting Fence 1 where some kerogen partings have high reflectivities and exhibit the general characteristics of an 'anthracitic' vitrinite or low-reflectivity inertinite. Pyrobitumen is thought to have formed at temperatures up to 220°C. Confirmation of localised regional heating within the Hay River-Toko Syncline area is given by the presence of doubly terminated quartz crystals in the Red Heart Dolomite. These contain fluid conclusions consisting of saline water in immiscible relationship with hydrocarbon gas. A realistic growth temperature is considered to be about 250°C (N. Russell, R.W.T. Wilkins).

The relationship between organic carbon and phosphorite in the Beetle Creek and Inca Formations is being evaluated on material from BMR Duchess 14 and 14A. There is an inverse relationship of total carbon and organic carbon between the shales and the phosphorites. Gas chromatographic analysis of the saturate fraction of the extractable hydrocarbons and elemental analysis of the kerogen suggest that the hydrocarbons in the phosphorites have a different organic source to that of the associated shales (M.W. Sandstrom).

ECONOMIC GEOLOGY

A thin oil shale interval has been discovered in BMR Mount Isa 1 adjacent to the Barkly Highway. Black shales in a dominantly carbonate sequence are thought to represent the feather edge of the Inca Formation which now becomes prospective. Oil yield has been analysed by Fisher Assay (pyrolysis) by the Australian Coal Industry Research Laboratory (Rockhampton), and source rock analysis has been undertaken by Robertson Research. Preliminary figures indicate a measured oil yield of 80-104 litres/tonne over the interval 107.56-119.49 m. Total organic carbon runs to 16.60% in the same interval (D. Gibson).

McARTHUR BASIN PROJECT

Compiled by

K.A. Plumb, Project Co-ordinator

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1. BMR officer, not a member of Geological Branch.
2. CSIRO officer.
3. USSR Academy of Science.
4. Part-time only

The basic aim of the McArthur Basin Project is to elucidate the evolution of the McArthur Basin, using stratigraphic, sedimentological, geochemical, geophysical, tectonic, and other studies, and to apply this information to the understanding of the genesis of ore deposits in the region.

OBJECTIVES OF 1979 PROGRAM

The main objectives of the 1979 program were:

(1) Continue the study of the sedimentology and palaeogeography of the Wollogorang Formation, Masterton Formation, Mallapunyah Formation, and Amelia Dolomite;

(2) Continue the study of the sedimentology, palaeogeography, and micropalaeontology of the Balbirini Dolomite, Dungaminnie Formation, and their stratigraphic equivalents;

(3) Carry out a mineralogical, sedimentological, and geochemical study of the Eastern Creek Pb-Ba deposit;

(4) Carry out a preliminary biostratigraphic study of the stromatolites of the McArthur Group;

(5) Investigate the application of LANDSAT data to mapping and mineral exploration in the McArthur Basin;

(6) Commence laboratory measurements on magneto-stratigraphic samples collected during 1978;

(7) Interpret the data from the 1978 magneto-telluric and gravity surveys across the Wearyan Shelf and eastern Batten Fault Zone, to determine the applicability of the methods to: (a) defining the configuration and depth of basement beneath the McArthur Basin; (b) defining thickness variations within the basin succession; (c) locating and defining the form of major structures; with the immediate aim of defining the basement and McArthur Basin succession beneath concealed areas of the Wearyan Shelf, immediately to the east of the Emu Fault.

(8) Extend the areal coverage of the magneto-telluric and gravity surveys, particularly westward across the Batten Fault Zone and Bauhinia Shelf.

(9) Carry out a seismic refraction/reflection survey along a 600 km traverse across the Bauhinia Shelf, Batten Fault Zone, and Wearyan Shelf, in order to investigate (a) the deep structure beneath the McArthur Basin, (b) the structural differences on the east and west sides of the Emu Fault, (c) define rock layers within the McArthur Basin succession.

REPORTING OF RESULTS

1. The results of the 1977 fieldwork have been released (Record 1978/54).

2. Quarterly progress reports of research and principal results have been distributed (Records 1979/15, 16, 44, and 57). In particular:

(a) major field geological results and detailed stratigraphic sections from the 1978 fieldwork are summarised in 1979/15 and 1979/44;

(b) Bouguer anomaly profiles and preliminary interpretation from the 1978 gravity survey are in 1979/44;

(c) a preliminary interpretation of the 1978 magneto-telluric survey is described in 1979/57.

3. M.D. Muir (1979) has proposed a sabkha depositional model for a profile through the Mallapunyah Formation and Amelia Dolomite (BMR Journal 4(2), 149-162), and Muir & others (in press) have applied the groundwater and evaporitic regimes of the Coorong Lakes of South Australia to the Yalco Formation (SEPM Special Publication).

GEOLOGICAL RESEARCH
(M.J. Jackson, Task Leader)

REGIONAL STRATIGRAPHIC STUDIES (M.J. Jackson, M.D. Muir)

'Abner Range area'

Systematic mapping of the Mallapunyah-Kilgour and parts of the adjoining 1:100 000 Sheet areas ('Abner Range area' of Fig. D2), which covers a total of about two standard 1:100 000 sheet areas and was almost completed in 1978, was completed during 1979. Photo-interpretation and map compilation at photoscale (1:25 000) is in progress, for eventual compilation at 1:100 000 scale.

Bauhinia Downs-Mount Young 1:250 000 sheet areas

Most field research during 1979 was carried out outside the 'Abner Range area' (Fig. D2). Helicopter and vehicle traverses were carried out in several areas where it was suspected that the geology shown on the first edition maps required revision.

In the Billengarrah Creek area the strike ridges of silicified rocks, previously mapped as Billengarrah Formation, comprise mostly Mount Birch

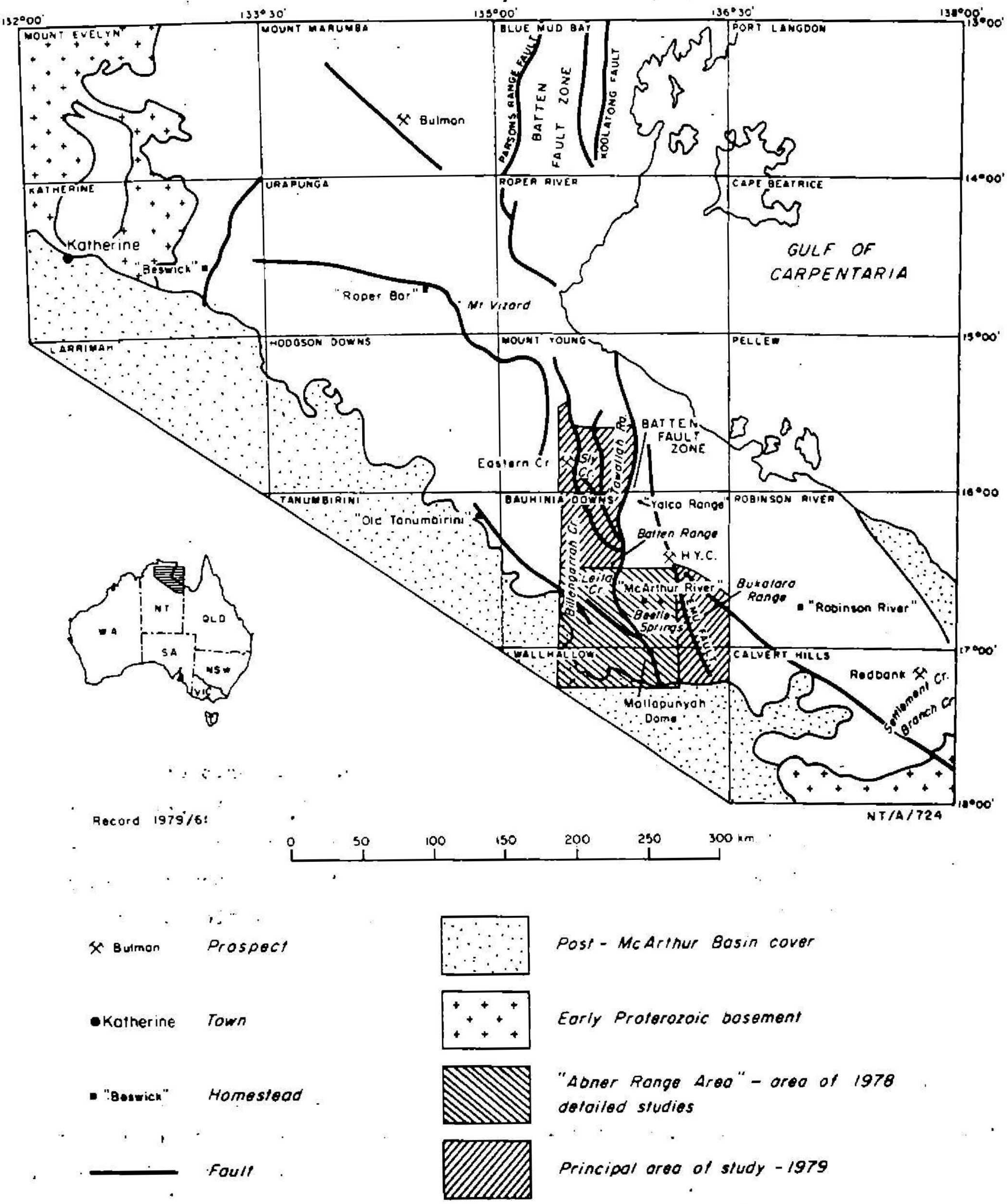


Fig. D2 Locality map, McArthur Basin Project, 1979, showing 1:250 000 Sheet areas

Sandstone and Kookaburra Creek Formation, overlying most of the Umbolooga Subgroup. Elsewhere in the region silicified representatives of a variety of McArthur Group units had been assigned to the Billengarrah Formation. The name will be abandoned when all units have been correctly identified.

Along the eastern side of the Tawallah Range, some areas shown as Festing Creek Formation have been identified as Settlement Creek Volcanics and Wollogorang Formation, whilst outcrops shown as Warramana Sandstone variously include ridges of Masterton Formation, Tatoola Sandstone, Bukalara Sandstone, and Cretaceous rocks. This further supports the recommendation of Plumb & Brown (1973) that use of the terms Festing Creek Formation and Warramana Sandstone be discontinued. The Settlement Creek Volcanics had previously not been recognised in this part of the Batten Fault Zone.

On the western side of the Batten Range, a fine-grained volcanic rock has been identified at the base of the Tatoola Sandstone.

Some newly discovered and previously inaccessible inliers, beneath the Bukalara Sandstone of the Bukalara Plateau, were visited by helicopter, where representatives of almost the complete McArthur Group sequence were identified along the eastern side of the Emu Fault.

REGIONAL CORRELATIONS (M.D. Muir)

Balbirini Dolomite and equivalents

Regional identification of marker beds, first identified during 1977-78, has confirmed correlations (Plumb & Brown, 1973) of the Balbirini Dolomite with the Stott Formation and Kookaburra Creek Formation (Table D1). In addition, the Smythe Sandstone and Mount Birch Sandstone can now be correlated with the basal arenite of the Balbirini Dolomite.

The same marker beds were identified in several sections of Kookaburra Creek Formation/Mount Birch Sandstone and Mount Rigg Group in the Urapunga, Katherine, and Mount Marumba Sheet areas, leading to the correlations shown in Table D2. The Margaret Hill Conglomerate is tentatively correlated with conglomerates in the Batten Subgroup.

The geographical extent of the pre-Balbirini Dolomite unconformity is very large, and the unconformity plane cuts down through all units of the McArthur Group, and thus represents a considerable hiatus. It is of comparable regional significance to that below the base of the Roper Group. It is

	BALBIRINI AREA		BATTEN CREEK AREA		EASTERN CREEK AREA	
	Formation	Marker Beds	Formation	Marker Beds	Formation	Marker Beds
ca. 600 m thick	Dungaminnie Formation		Not present		Not present	
ca. 1 km thick	Balbirini Dolomite	Upper oolite Recrystallised dolomite Kussiella bed Sandstone sequence 'Balbirina prima' Lower oolite Evaporite sequence	Stott Formation	Sandstones 'Balbirina prima' Lower oolites Evaporite sequence	Kookaburra Creek Formation	Upper oolites Flat-bedded and laminated dolomite Kussiella bed Sandstones 'Balbirina prima' Lower oolites Thin evaporite sequence
		Basal arenite Fine micaceous chert - carbonate grain sandstone	Smythe Sandstone	Chert-carbonate grain conglomerate and sandstone	Mount Birch Sandstone	Chert-carbonate grain conglomerate and sandstone
	UNCONFORMITY		UNCONFORMITY		UNCONFORMITY	
	BATTEN SUBGROUP UMBOLOOGA SUBGROUP		BATTEN SUBGROUP UMBOLOOGA SUBGROUP		BATTEN SUBGROUP UMBOLOOGA SUBGROUP	

Table D1. Correlation of marker beds, Balbirini Dolomite and equivalents, Bauhinia Downs and Mount Young Sheet areas.

BALBIRINI AREA	BATTEN CREEK AREA	EASTERN CREEK AREA	ROPER BAR - MOUNT VIZARD AREA	BESWICK AREA
Balbirini Dolomite	Stott Formation	Kookaburra Creek Formation	Kookaburra Creek Formation Yalwarra Volc. Mbr. Kookaburra Creek Formation	Beswick Creek Formation Dook Creek Formation
(Basal arenite)	Smythe Sandstone	Mount Birch Sandstone	Mount Birch Sandstone	Bone Creek Formation
UNCONFORMITY	UNCONFORMITY	UNCONFORMITY	UNCONFORMITY	UNCONFORMITY
BATTEN SUBGROUP	BATTEN SUBGROUP	BATTEN SUBGROUP		Margaret Hill Conglomerate
UMBOLOOGA SUBGROUP	UMBOLOOGA SUBGROUP	UMBOLOOGA SUBGROUP	Vizard Formation	

Table D2 Proposed correlation of units, Balbirini Dolomite and equivalents, southern and western McArthur Basin.

suggested that all the units of the Balbirini Dolomite and equivalents should be placed into a single group (Table D2). These new correlations are of considerable regional geological and economic significance.

Vizard Formation

In the Urapunga, Roper River, and northern Mount Young Sheet areas, the Mount Birch Sandstone overlies the Vizard Formation; the Vizard Formation has been correlated with an unknown part of the Batten or Umbolooga Subgroups (Plumb & Brown, 1973). Although it has since been shown that the Vizard Formation in Mount Young Sheet area is simply the silicified equivalent of nearby Umbolooga Subgroup outcrops (unpublished data, K.A.P., 1973, M.D.M., 1979), facies differences and lack of marker beds have defied attempts to correlate the type section at Mount Vizard (K.A.P.).

In the light of later knowledge of McArthur group units, the Mount Vizard section was visited in 1979, and relatively straightforward correlations (Table D3) are now suggested with the Umbolooga Subgroup and the 'Upper' Lynott Formation of the Batten Subgroup (M.D.M.).

The Mount Reid Beds (Tawallah Group equivalents), which underlie the Vizard Formation near Roper Bar Police Station, most resemble the rock types of the Masterton Formation.

REGIONAL UNCONFORMITIES (M.D. Muir)

Correlation of McArthur Group rocks in the area from Batten Range to Roper Bar is complicated by severe alteration of the rocks during weathering cycles of several ages. Unconformities occur throughout the sequences studied, and the rocks immediately below these unconformities are invariably either recrystallised (if carbonates) or totally silicified. Primary structures can be obliterated, so that the silicified or recrystallised carbonate rocks contain little evidence of their original character. The weathering affects all formations, but appears to be particularly severe at the sub-Balbirini Dolomite, sub-Limmen Sandstone, and sub-Cretaceous unconformities. Silicified rocks occur below all these unconformities, in both surface exposure and in drill core.

It is important to distinguish the major unconformities, because mineralisation is associated with the sub-Balbirini Dolomite and sub-Limmen Sandstone surfaces. However, in many areas the unconformity planes are

McARTHUR RIVER AREA		MOUNT VIZARD AREA	
BATTEN SUBGROUP	Lynott Formation	Vizard Formation	White sandstone and thin dolomite
UNCONFORMITY			? UNCONFORMITY ?
UMBOLOOGA SUBGROUP	Reward Dolomite		Sandstone and dolomite with tuffite
	Barney Creek Formation		Green shales with tuffite
	Teena Dolomite / Emmerugga Dolomite		Sandstone and dolomite
	Tooganinie Formation		Shale and sandstone
	Tatoola Sandstone		Conspicuous white sandstone
	Amelia Dolomite		Dolarenite with abundant gypsum casts
	Mallapunyah Formation		Dolomitic and ferruginous sandstone
			? UNCONFORMITY ?
	Masterton Formation	Mount Reid Beds	

Table D3 - Proposed correlation of Mount Vizard Formation at Mount Vizard with McArthur Group units at McArthur River coincident or nearly so, and in many cases the overlying rocks have been removed by subsequent erosion. It is therefore necessary to consider criteria which can identify the various unconformity surfaces, such as the nature of the regoliths and the overlying basal conglomerates.

Regoliths up to 1 m thick are developed on the sub-Limmen Sandstone and sub-Cretaceous surfaces. These regoliths generally consist of unoriented, very angular fragments of locally-derived silicified carbonates, in a matrix of finer grains of similar material. The Limmen Sandstone regolith is slightly to moderately ferruginous and weathers to a pale brown colour. The Cretaceous regolith is similar, but is extremely ferruginous and weathers to dark-red or blue-black. The basal Limmen Sandstone is frequently conglomeratic, with moderately to sub-rounded pebbles in a fine to medium-trained sandstone matrix. The pebbles are almost invariably chert-carbonate. In some places, very micaceous red or green fine-grained sandstones overlie the basal conglomerate, before a lithological change to the more usual white or pink Limmen Sandstone takes place. The basal Cretaceous is frequently a grain-supported conglomerate and contains well-rounded to very well-rounded pebbles and boulders of Roper Group and Tawallah Group sandstones, with only a minor contribution from McArthur Group silicified carbonates.

The sub-Balbirini Dolomite unconformity is different. The rocks beneath the unconformity are very strongly silicified, except the Amos Formation which is a recrystallised carbonate. This formation shows signs of extensive pressure solution, in the form of stylolites, and the top surface of the formation contains abundant calcrete pisoliths, which formed in the vadose zone after deposition of the Amos Formation dolarenites. Its lateral equivalent, the Looking Glass Formation, is invariably silicified, but sufficient detail remains to show that it was originally a sequence of stromatolitic and oolitic carbonates, with interbeds of flake breccia and fine-grained sandstone. The silicified carbonates of this formation are extremely vuggy and appear to have a high secondary porosity. This porosity resembles porosity developed when recently deposited carbonates are uplifted into the vadose zone. This enhanced porosity has provided an ideal trap for liquid hydrocarbons in many major Phanerozoic oilfields. In drill core, the Looking Glass Formation contains abundant solid bitumen in the vugs. The bitumen forms either six-sided crystals, globules, or completely fills the vugs. It is very lustrous, has a conchoidal fracture, and it may be pyritic.

DETAILED SEDIMENTOLOGICAL STUDIES

Poor outcrop in the northern Bauhinia Downs Sheet area made it apparent that detailed studies would yield very little further data then that collected farther south during 1978. The objectives were therefore expanded so as to include the Roper River-Katherine area and most of the Tawallah Group.

TAWALLAH GROUP (M.J. Jackson)

McDermott Formation

One incomplete section was measured through the McDermott Formation in the Branch Creek area (Fig. D2) to establish a reference section. Here the formation comprises approximately 95 m of mainly subtidal, intertidal, and supratidal sandy carbonates showing a sabkha imprint ('cauliflower cherts' and gypsum crystal pseudomorphs), and has many similarities with the Amelia Dolomite (including intraclast breccias, oolites, domal stromatolites, and teepee structures). The upper 12 m of the formation comprises intensely-silicified carbonates, containing recognisable algal, oolitic, and intraclast structures. In contrast, the directly overlying Sly Creek Sandstone, a porous, fine to medium-grained quartz sandstone, is unsilicified. This possibly indicates the presence of an important stratigraphic break accompanied by a period of surface silicification, which may be useful as a regional marker bed.

Sly Creek-Rosie Creek Sandstones

Continuous stratigraphic sections, hundreds of metres thick through well-exposed sequences of these formations, were measured in the northwestern Tawallah, central Tawallah, and Batten Ranges (Fig. D2), and were complemented by spot observations in other areas. In two sections a distinctive oligomictic quartz breccia, a few metres thick, was recognised near the middle of the sandstone sequence. This breccia is interpreted as a silicified regolith indicating a previously unrecognised widespread break in sedimentation. Elsewhere, this period of erosion is probably represented by a 5 m-thick oligomictic pebble to cobble conglomerate bed. On a broad scale, the sandstones below the breccia bed are generally fine-grained, well-sorted quartz sandstones with sedimentary features of probable shallow-marine origin (herringbone and low-angle planar cross-stratification, symmetrical ripples). The sandstones above the breccias are more commonly less well-sorted and coarser-grained and are probably largely fluviatile; they are characterised by large-scale high-angle scoop cross-stratification, with numerous pebble beds or scattered pebbles of quartzite. On a detailed scale, however, the various sandstone types are represented throughout the sequence.

Glauconite is present both above and below the breccia bed in one section, whilst very little was found in the other sections, although all sections should have finished with the Rosie Creek Sandstone, as indicated on the relevant 1:250 000 Sheets. The division into Sly Creek Sandstone (without glauconite) and Rosie Creek Sandstone (with glauconite) is questioned.

Settlement Creek Volcanics

Owing to deep weathering and poor outcrop little additional petrological information was obtained. However, in contradiction to the original mapping, the Settlement Creek Volcanics do form part of the sequence in the Tawallah Range. Along the southwest and northeast margins of the Tawallah Range, poorly outcropping chloritised and epidotised fine-grained basic volcanics, tuffs, and agglomerates separate the Sly Creek/Rosie Creek sequence from the overlying Wollogorang Formation. However, in the Batten Range area, there appears to be a conformable gradational sequence from a very thick Sly Creek-Rosie Creek Sandstone sequence into a thicker than normal, less dolomitic micaceous Wollogorang Formation sequence.

Wollogorang Formation

In general, the Wollogorang Formation crops out well throughout most of the southern part of the basin. Because it contains widespread disseminated mineralisation and is related to the subeconomic copper-bearing breccia pipes at Redbank, it was studied in detail. Five detailed sections were measured along Settlement Creek, which is designated as the type area. Here the formation can be subdivided into five distinctive units: 1) an intertidal to sub-tidal carbonate interval, up to 60 m thick, with columnar stromatolites and organic-rich concretions at the base; 2) a 30 m-thick coarse-grained and conglomeratic cross-stratified dolomitic sandstone interval; 3) a 5-10-m-thick evaporitic interval, comprising ferroan dolomites with gypsum pseudomorphs capped by a solution-collapse breccia; 4) a 10-15 m-thick very fine-grained carbonate interval, with domal and columnar stromatolites and halite pseudomorphs; and 5) an upper quartz sandstone unit of variable thickness. Only minor variations in lithology and thickness along a strike belt some 40 km long were evident in the Settlement Creek area. An almost identical sequence was measured in the Robinson River Gorge (100 km to the northwest), indicating widespread uniform conditions for areas east of the Calvert Fault.

Although a similar depositional setting is indicated for the lowest beds of the formation in much of the rest of the basin, marked differences are apparent in the upper three-quarters of the formation west of the Emu Fault. Near the H.Y.C. prospect a thin sequence of silty dolostone is all that is preserved; in the Batten and Yalco Ranges micaceous siltstone with thin interbeds of dolomite and sandstone are present, whilst in the western part of the Tawallah Ranges, silty carbonates are predominant. At the western margin of the basin, the formation is represented by 60 m of laminated (?)lacustrine claystone and siltstone.

BMR Mount Young 2 was drilled through the Wollogorang Formation in the Eastern Creek area. At the end of September, 1979, it had intersected a 100 m-thick sequence of interbedded light and dark grey dolomitic siltstone and mudstone, with both disseminated pyrite and chalcopyrite and thin beds of highly-pyritic shale. As in surface outcrops, the mineralisation often concentrates within and around concretions in the lower part of the formation.

Masterton Formation

The Masterton Formation comprises mainly quartz sandstone and conglomerate, that crops out well in rugged ranges or prominent strike ridges and is therefore amenable to detailed investigation. The 1978 field research in the southern part of the basin had suggested that the formation was a fairly uniform littoral sandstone sequence, less than 100 m thick. However, field research during 1979 showed the formation to be variable in both thickness and character throughout the rest of the area. In the Batten Range it consists of fairly uniform fine to medium-grained quartz and ferruginous sandstone, with rare conglomeratic interbeds, and it is over 900 m thick. In the Yalco Range it is more than 600 m thick, but consists largely of very coarse-grained quartz sandstone and pebble to cobble conglomerate. In contrast, in the southern Tawallah Range, coarse-grained conglomeratic sandstone comprises only the lower 80 m of the formation. The remainder (700 m) is composed of medium-grained quartz sandstone with thick intervals of poorly-outcropping fine-grained feldspathic sandstone and micaceous siltstone.

An important discovery is a previously unrecognised igneous event within the Masterton Formation, at several localities within the Batten Fault Zone. A small coarse-grained quartz porphyry plug with overlying lavas and volcaniclastics is locally present at about the middle of the formation in the Eastern Creek area. A poor outcrop of deeply weathered (?)basic volcanics was found in the Batten Range, also about half-way up the section. In other areas (e.g. Tawallah and Yalco Ranges), this event can be inferred from the first appearance of volcanic fragments as pebbles within the conglomeratic sandstone sequences. It is likely that this volcanic activity is synchronous with volcanic episodes near the western and eastern margins of the basin (Tanumbirini Volcanic Member and Hobblechain Rhyolite Member, respectively); but they are not thought to be related to the Gold Creek Volcanic Member.

Attempts were made to define the contact relationships between the Tanumbirini Volcanic Member and the Masterton Formation Sandstones. The lower contact of the member was not found, but the character of the upper contact indicates that extrusion of the volcanics must have initiated strong local relief, which led to the deposition of penecontemporaneous volcaniclastic pebble to boulder conglomerate beds.

McARTHUR GROUP

Mallapunyah Formation (M.J. Jackson)

Very little additional detailed information was obtained, due to the lack of outcrop. However, in a section 20 km northeast of the type section at Mallapunyah, the thickness is reduced to about 65 m, and the formation consists largely of friable ferruginous sandstone, rather than dolomitic siltstone. In its upper part, the formation consisted of more typical dolomitic siltstone with cauliflower cherts, and was overlain by a typical Amelia Dolomite sequence.

Amelia Dolomite (M.J. Jackson)

As with the Mallapunyah Formation, the lack of continuous, well-exposed sections hindered further detailed sedimentological studies. However, information from a company drillhole and from widely-spaced outcrops indicates that, except for minor detail, the features seen in the Mallapunyah and Leila Creek areas are typical of the formation over a wide area.

Balbirini Dolomite and equivalents (M.D. Muir)

On the available evidence, the depositional centre of the Balbirini Dolomite and equivalents (Table D1) lies to the northwest of that of the main McArthur Group; it is best developed in areas where the main McArthur Group is thin or poorly developed (Urapunga Tectonic Ridge). The Balbirini Dolomite and equivalents appear to have been deposited in a basin with a similar distribution to that of the Roper Group, although separated from the latter by a major unconformity.

The importance and wide distribution of the unconformity beneath the Balbirini Dolomite and equivalents has been further demonstrated during 1979. The Balbirini Dolomite and equivalents now overstep and rest on all units of the McArthur Group.

The basal arenite unit ranges from fine red micaceous sandstone to coarse boulder conglomerate. Its nature appears to be related to the character of the substrate: boulder conglomerate occurs where the substrate is silicified in outcrop, whereas fine sandstone overlies altered carbonates of the Amos Formation; up to five thin beds of pebble conglomerate occur within the fine sandstone.

All of the rocks on which the Balbirini Dolomite rest are very weathered, both in outcrop and in drill core which intersected the contact between the basal Balbirini Dolomite and underlying totally-silicified Looking Glass Formation. It is, therefore, reasonable to assume that much of the weathering is pre-Balbirini.

Drilling in the Balbirini Dolomite (M.D. Muir)

(1) A 153-m hole (Bauhinia Downs 3) was drilled northwest of McArthur River homestead, to examine the nature of a 70-m interval at the top of the Balbirini Dolomite which never crops out. The hole was spudded in on a conspicuous sandstone bed in the overlying Dungaminnie Formation, and the unknown interval proved to be red and green dolomitic siltstone with conspicuous dolomite concretions. The hole terminated in flat-laminated dololutite in the Balbirini Dolomite.

(2) At Beetle Springs, a 37-m hole (Bauhinia Downs 4) intersected the contact between the Balbirini Dolomite and the unconformably-underlying Looking Glass Formation. The basal Balbirini Dolomite is a conglomeratic sandstone. At the actual unconformity, there is a 30-cm bed of white claystone, underlain by completely silicified carbonate and fine sandstone of the Looking Glass Formation. The Looking Glass Formation is stromatolitic in places, but its most conspicuous feature is its vugginess. The vugs are generally bitumen-filled, with minor pyrite in the bitumen. Pyrite, both fine and coarse-grained, and both disseminated and concentrated, is abundant, and traces of chalcopyrite, galena, sphalerite, barite, and dolomite also occur.

(3) A 50-m stratigraphic hole was drilled at the Eastern Creek Pb-Ba prospect to provide fresh material for petrological and isotope studies.

MINERALISATION - BALBIRINI DOLOMITE EQUIVALENTS (M.D. Muir)

Most of the mineralisation occurs in the Kookaburra Creek or Dook Creek Formations. Lead-copper mineralisation occurs at or near the present land surface at Bulman, and not very far below the pre-Limmen Sandstone unconformity. The galena is coarse-grained, and occurs in stratabound bodies which parallel the land surface. C.R.A.E. drill core of the Dook Creek Formation at Bulman is not particularly metalliferous, but does contain galena, sphalerite, and copper minerals in breccias and veins in a number of short intersections. In essence, the Bulman occurrence is very similar to the Eastern Creek lead-barite deposit.

Eastern Creek lead-barite deposit (M.D. Muir)

A combined study of the Eastern Creek Pb-Ba deposit has commenced with T.H. Donnelly (Baas Becking Laboratory) and R. Wilkinson (CSIRO). Petrology and X-ray microanalysis of drill core material have been completed, and work on the stable isotopes (T.H.D.) and fluid inclusions (R.W.) is in progress.

Regional mapping indicates that the barite occurrences are widespread, and appear to be related to the pre-Limmen Sandstone land surface. The host rocks are mainly dolomite and chert, and a complex mineral paragenesis is indicated. Copper minerals are usually associated with the galena, and the present evidence indicates that the galena and barite mineralisation are essentially different events.

STROMATOLITE BIOSTRATIGRAPHY (M.R. Walter, I.N. Krylov, M.D. Muir)

Following collection of material during 1978, five forms of distinctive columnar stromatolites have been described from the Amelia Dolomite, Tooganinie Formation, Emmerugga Dolomite, and Balbirini Dolomite. Some forms closely resemble Lower Riphaean forms from the USSR, and indicate considerable potential for stratigraphic correlation. Some forms are of considerable environmental significance (Record 1979/44). Publications describing the stromatolites are being prepared.

REMOTE SENSING (C.J. Simpson, W.J. Perry)

Preliminary experiments have indicated that Landsat data may have some potential in mineral exploration in the McArthur Basin and false-colour images have delineated small, previously undetected inliers of McArthur Basin rocks beneath the Cambrian Bukalara Sandstone.

During August, ground and helicopter spectral radiometer measurements were made over selected rock, soil, and vegetation targets near McArthur River. The data will be used to calibrate Landsat data, with the objective of developing computer-assisted techniques for the discrimination of rock types and the detection of mineralisation.

PALAEOMAGNETIC RESEARCH

(M. Idnurm (Task Leader), J.W. Giddings)

Half of the 200 specimens from the 1978 collection of magneto-stratigraphic samples from the McArthur Basin have been prepared. This includes material from the McArthur Group, Kombolgie Formation, Packsaddle Microgranite, Hobblechain Rhyolite, Wollogorang Formation, Edith River Volcanics, and Westmoreland Conglomerate. A series of pilot thermal demagnetisations was carried out on the new material. The main program of measurements has however been delayed by the late arrival of commercial demagnetisation equipment from USA. This equipment permits a more rapid heating of samples than the existing demagnetisers at the Black Mountain Laboratory, and is therefore expected to reduce viscous magnetisation behaviour due to mineralogical changes during demagnetisation, to which carbonate rocks are particularly susceptible.

The Packsaddle Microgranite and Hobblechain Rhyolite pilots give directions similar to those found in the Masterton and basal Mallapunyah Formations in 1978. The consistency of directions between well separated sites (the volcanics were sampled at Wollogorang Station approximately 200 km away from the Mallapunyah/Masterton sites), and for different lithologies, for roughly time equivalent units, is encouraging, though not conclusive evidence that the remanence directions are primary.

The Westmoreland Conglomerate, like the Kombolgie Formation, shows a large scatter between pilot directions. The reasons for this scatter are not clear at present and will be investigated. The scatter could be due, for example, to secondary remanence resulting from weathering, or to the nature of the Lower Carpentarian geomagnetic field.

SUBSURFACE STRUCTURAL RESEARCH

Preliminary modelling of the gravity and magneto-telluric data collected during 1978 has revealed that both methods have potential for resolving alternative models of the subsurface structure and basement configuration beneath the McArthur Basin. However, at the present time, the methods are indicating conflicting models. Completion of modelling of the magneto-telluric data has been delayed by the resignation of key staff, while further gravity modelling is dependent on data collected during 1979. Both surveys have been continued in the field during 1979.

During 1979 a seismic refraction/reflection survey was carried out across the basin. The refraction line is designed to determine the deep crustal structure across the basin, and in particular to investigate the structural differences on the east and west sides of the Emu Fault, while the reflection recordings should provide additional data to aid the interpretation of the gravity and magneto-telluric surveys.

These combined surveys provide a continuous profile of geophysical data right across the southern McArthur Basin (Fig. D3). It is proposed to integrate the models and constraints derived from these surveys with the basin-wide airborne magnetic and radiometric data and helicopter reconnaissance gravity data, to derive a geophysical model for the deep structure of the whole McArthur Basin and assess the priority for future work.

MAGNETO-TELLURIC RESEARCH (A.G. Spence (Task Leader), J.P. Cull, D. Kerr, B. Liu, J.A. Major, J. Whatman)

Interpretation, 1978 data

This survey was designed to investigate the structure across and to the east of the Emu Fault (Fig. D3). Preliminary 2-D modelling of the main line has been carried out, from Batten Creek across the Emu Fault to the northwestern Robinson River Sheet area, but further detailing is required near the Emu Fault. 1-D modelling is adequate for the easternmost stations, in Robinson River and Calvert Hills Sheet areas.

Highly resistive basement is about 3.5 km deep in the Robinson River Sheet area, increasing westwards to about 4.5 km near the Emu Fault. The basement is overlain by a conductive sequence, consistent with sandstones of the Tawallah Group, and there is no significant thickness of any resistive rocks that can be correlated with the McArthur Group. The increase in depth to basement corresponds with the appearance of a 1-km thick conductive layer at the top of the section, which may be correlated with a known shallow basin of Roper Group rocks.

To the west of the Emu Fault, a layered sequence of highly conductive rocks, about 5 km thick, may be clearly identified with carbonate rocks of the McArthur Group. This overlies a conductive layer, the thickness of which has not yet been computed, which correlates with the Tawallah Group.

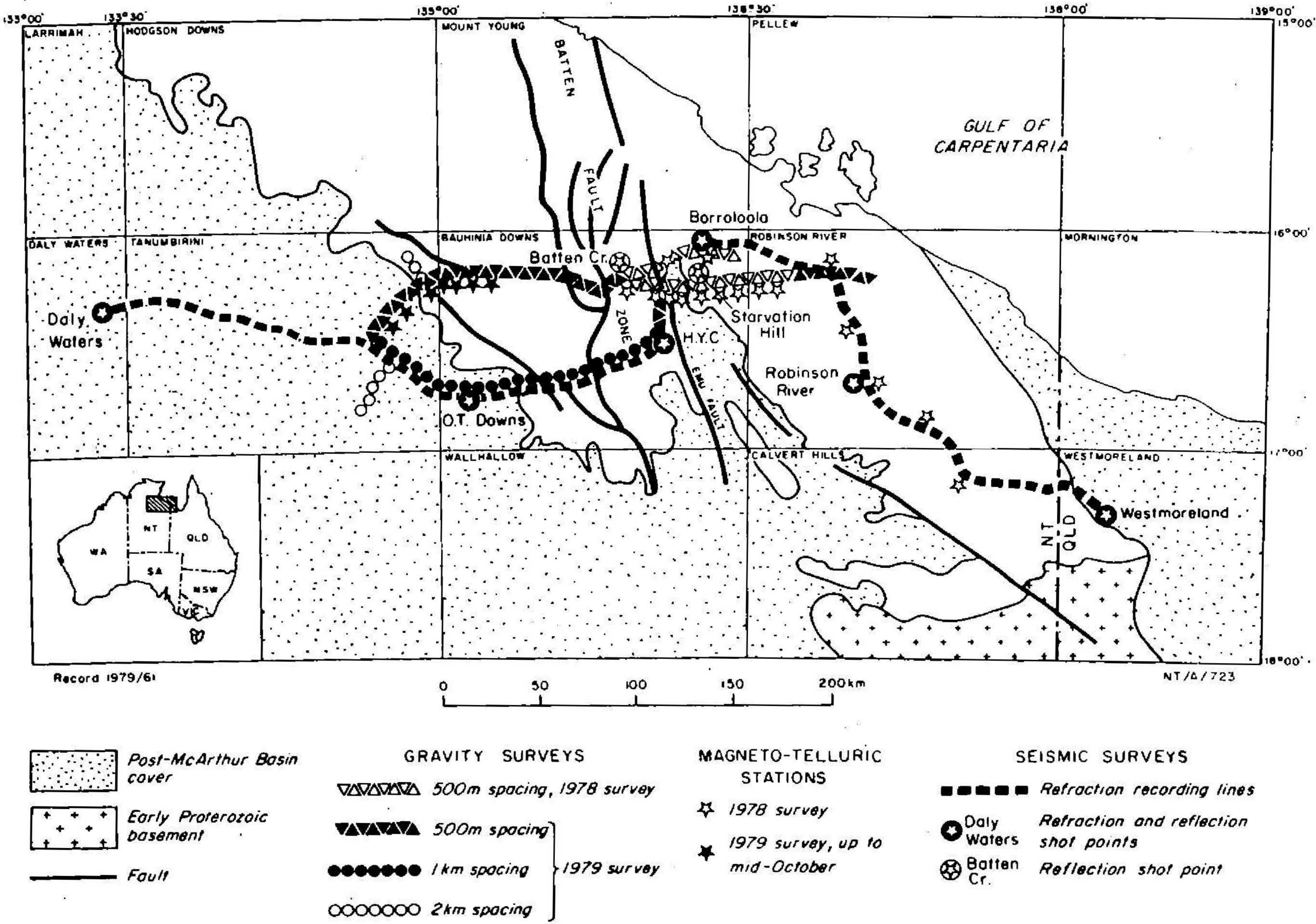


Fig. D3 Locality map, geophysical surveys, southern McArthur Basin, 1978 - 79, showing 1:250 000 Sheet areas

The thickness of Tawallah Group rocks east of the Fault, and of McArthur Group rocks west of the Fault, agrees well with that predicted from surface geology. There is clearly a marked difference in thickness of the McArthur Group across the Emu Fault, in the area of the survey. The preliminary modelling clearly supports the previously postulated geological model for the form of the Batten Trough.

1979 Field Survey

The 1979 survey is designed to determine the structure of the McArthur Basin to the west of the Batten Fault Zone, and perhaps identify the concealed southwestern margin of the basin (Fig. D3). Staff unavailability, equipment availability, and equipment failures have combined to delay the commencement of acquisition of data until mid-September. Six sites had been recorded as at 8 October, and the survey was proceeding. Completion will be dependent on weather - both the temperature of sensitive equipment and the arrival of rain. No processing of data has been carried out yet.

GRAVITY RESEARCH (W. Anfiloff (Task Leader), R. Tracey)
Interpretation, 1978 data

Gravity observations made in 1978 were processed and a preliminary qualitative interpretation, along the main eastwest traverse (Fig. D3), was made. The results suggest a broadly undulate basement generally and a broad syncline east of the Emu Fault (Record 1979/44).

The absence of a regional change in gravity level across the Emu Fault suggests that the fault has no major vertical displacement or that there is no density contrast between the sediment and basement rocks in that area. The results of further gravity work in 1979, over a major syncline west of the Batten Fault Zone (Fig. D3) indicate that there must be a distinct density contrast; therefore the firm alternative interpretation appears to be the most likely. This interpretation is also supported by the presence of gravity anomalies of the type normally associated with faulting over other faults in the area, such as the Tawallah Fault.

A short-wavelength gravity high, of 3 mgal amplitude, in the vicinity of the Emu Fault, has been interpreted as the expression of a shallow, dense body, possibly similar in nature to the H.Y.C. orebody, which lies close to the fault some distance to the south of the main traverse.

1979 Field Survey

The main east-west traverse was extended westwards during 1979; observations were made at 500 m intervals right across the Batten Fault Zone and onto the Bauhinia Shelf, of the Bauhinia Downs and Tanumbirini Sheet areas (Fig. D3).

The gravity coverage of the McArthur Basn was also extended over a number of roads, at wider spacings (1 km or 2 km), principally to provide detailed gravity information on anomalous gravity features in the helicopter reconnaissance data, and further data on the extent of the Batten Trough. This 1979 work gave gravity observations, mainly at 0.5 km intervals, over about 450 km of traverse.

SEISMIC RESEARCH (C.D.N. Collins, J. Pinchin (Task Leaders); D. Pfister, D. Pownall, J. Williams)

During June and July, 1979, a seismic refraction/reflection survey was carried out in the McArthur Basin. One long refraction line (300 km) and one shorter line of 100 km were recorded on each side of the Emu Fault (Fig. D3).

For the long refraction lines, between Daly Waters and H.Y.C. Prospect 9, and between Borroloola and Westmoreland, shots of 2000 kg were fired and recorded at 21 stations at 15-km intervals. For the shorter traverses, between O.T. Downs and H.Y.C. Mine, and between Borroloola and Robinson River, the charge size was 400 kg and the 21 recording stations were positioned at 5-km intervals. Seismic reflections were recorded at each shot-point over a 3-km reflection spread and a 1-km cross-traverse. In addition, single shots were recorded by reflection spreads near Starvation Hill, on the eastern side of the Emu Fault, and at Batten Creek.

Reflection Survey (J. Pinchin, D. Pfister)

Good reflections were recorded at all locations, except at Daly Waters and at O.T. Downs. At Daly Waters it is thought that shallow high-velocity interbeds, of perhaps limestone or shale, prevented the vertical penetration of seismic energy; at O.T. Downs the deep weathering of the Cretaceous rocks was probably the reason for the lack of seismic reflections. At the other sites, good reflections were recorded from estimated depths of between 2 and 45 km; shallower reflections may be revealed by digital processing.

The seismic reflection data is being digitally processed by Geophysical Service International, Sydney; the processing includes time-variant filtering and deconvolution to enhance the data quality.

Shallow refraction. The first breaks along the reflection spreads were plotted to obtain information on weathering depths and shallow refracting horizons. In addition, a continuous shallow refraction profile was recorded along the Tablelands Highway near Mallapunyah Station (southern Bauhinia Downs Sheet).

The results showed generally high velocities at shallow depths. At Daly Waters, thin beds with velocities of around 4700 m/s were found at depths of 175 m, 325 m, and 450 m; these could be thin beds of limestone or shale. Near H.Y.C. Mine a velocity of 5640 m/s at 45 m depth probably correlates with the Emmerugga Dolomite. A 6400 m/s refractor at Borroloola probably marks the top of a sandstone unit of the Roper Group. It was hoped that the shallow refraction profiling in an area of good geological control near Mallapunyah would reveal a distinct refraction velocity for each of the major sedimentary rock units, but the area proved too complex for this simple profiling. However, velocities of around 5500 m/s are thought to be associated with the Tooganinie Formation; 6000 m/s may mark the top of the Leila Sandstone Member, and refractors with velocities 5300 m/s and 5800 m/s, but with conflicting dips, were associated with the Emmerrugga Dolomite.

Refraction Survey (C.D.N. Collins, D. Pownall, J. Williams)

All seismic refraction recordings were made using magnetic tape recorders, and playback of these is being done at BMR, Canberra. The analogue data will be digitised and processed on the BMR HP2100 computer. A few representative examples of the refraction records have been played back using a portable field-play-back system. The quality of records produced by this system is poor, and no filtering is possible to enhance the arrivals. However, the records which have been played back to date show that all shots were recorded to the maximum distance of their respective traverses.

A plot of the first-arrival time versus distance for the Daly Waters to McArthur River traverse has been made. No timing correlations have been applied and the distances are only approximate. Only two crustal phases can be clearly identified, but the scatter due to the uncorrected data and the poor quality playback may mask much of the detail. Mantle arrivals were recorded beyond about 200 km. No large differences in arrival-times are apparent between seismic waves travelling east and those travelling west, indicating that uniform horizontal layering is present between Daly Waters and McArthur River.

BAAS BECKING GEOBIOLOGICAL RESEARCH LABORATORY

SEDIMENTOLOGICAL STUDIES IN SPENCER GULF

by

R.V. Burne

STAFF: R.V. Burne, L. Pain, M. Tratt

The objectives of this program are to establish the sedimentological framework of Spencer Gulf environments to provide a geological context for associated microbiological and mineralogical studies, and to provide a model for the palaeogeographical interpretation of appropriate orebody host rocks.

In the past year the program continued to concentrate on the prograding coastal areas of the northern part of Spencer Gulf, especially in the vicinity of Fisherman Bay, Mambray Creek, Redcliff, and Wood Point (Fig. B1).

Radiocarbon ages have been determined from molluscs collected from beach ridges associated with these areas. A beach ridge on the landward edge of the Redcliff beach ridge complex yielded a ^{14}C age of 4510 ± 110 years B.P., the beach ridge system at Mambray Creek gave dates ranging from 2010 ± 90 years B.P. to 1270 ± 90 years B.P., whilst a stranded beach ridge at the rear of the supratidal plain at Fisherman Bay had an age of 1560 ± 80 years B.P.. More dates are required to establish the reliability of these figures.

The prograding areas are constructed largely from sediment derived from offshore areas of carbonate formation. Examination of vibrocores from various offshore facies indicated that Holocene sedimentation rates vary between about 1 cm/48 years and 1 cm/108 years. The sediments of these areas are carbonates, often very pure but locally containing admixtures of up to 60 percent terrigenous sediment, adjacent to the mouths of ephemeral streams. The skeletal components of these carbonates are dominated by bivalve, gastropod, benthic foraminifera, and bryozoan fragments. Variations of these components have been determined, with the assistance of J. Colwell, and are shown in Figure B2.

The organisation of the coastal complexes has been studied by considering the relationship between surface elevation, depositional environment, and extent of tidal inundation. This work uses detailed surveys of transects undertaken by the Department of Administrative Services, field observations of environments, and a frequency distribution for tidal inundation at all heights over the tidal range derived from the Port Pirie tide gauge records. Examples of these relationships are given in Figures B3 and B4. On

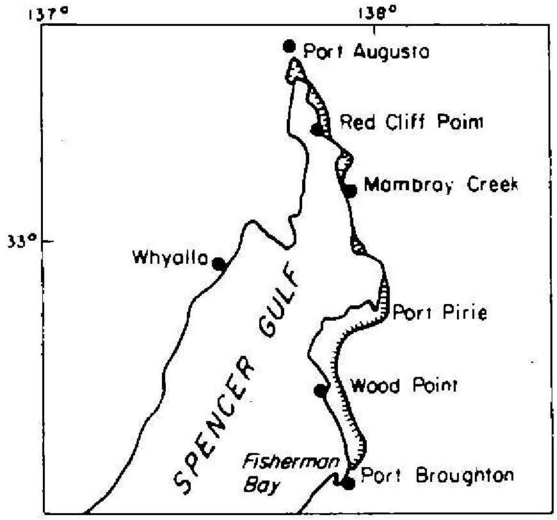


Fig. B1 Location of Spencer Gulf study area

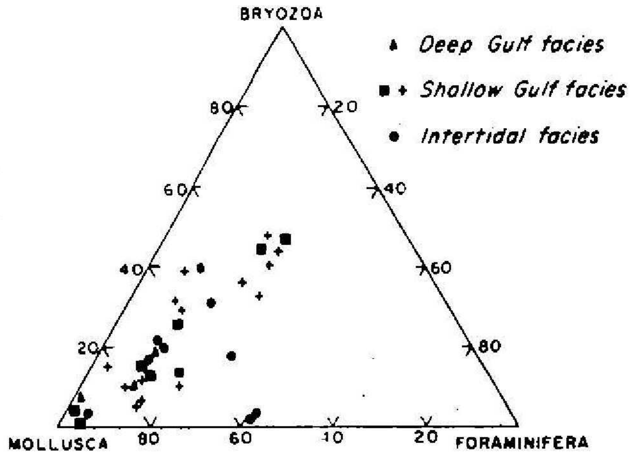


Fig. B2 Skeletal composition of carbonate sediments

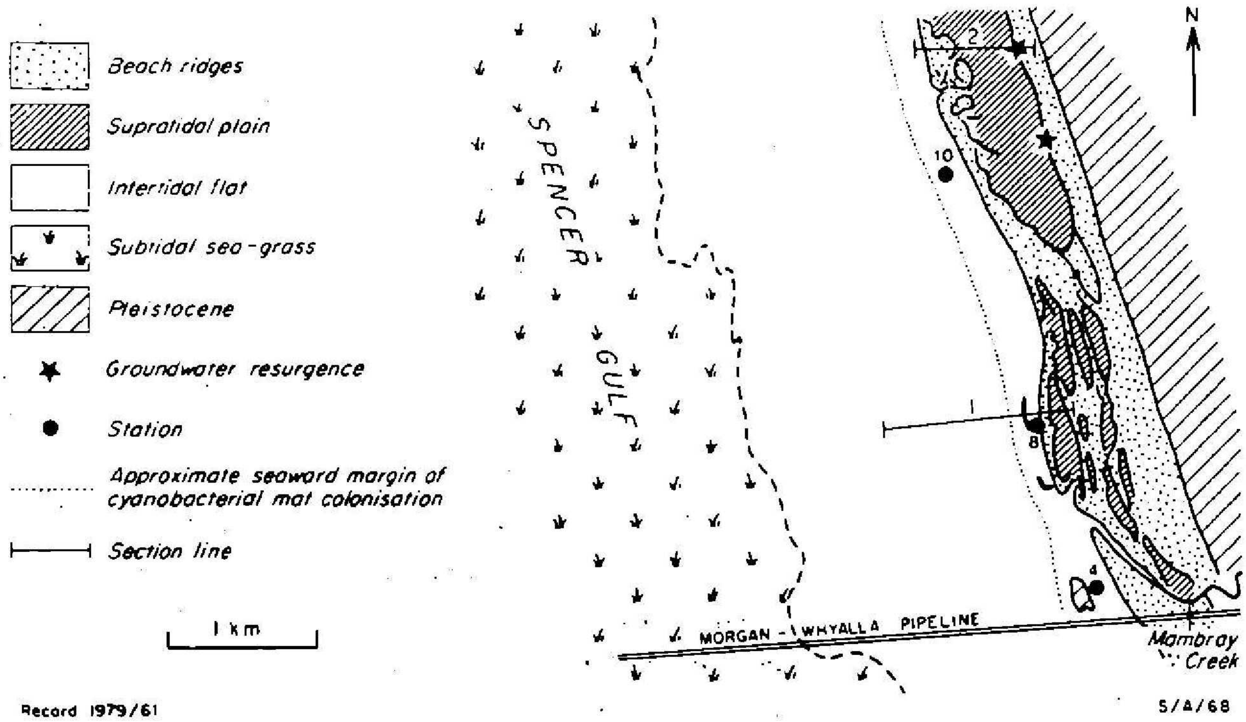
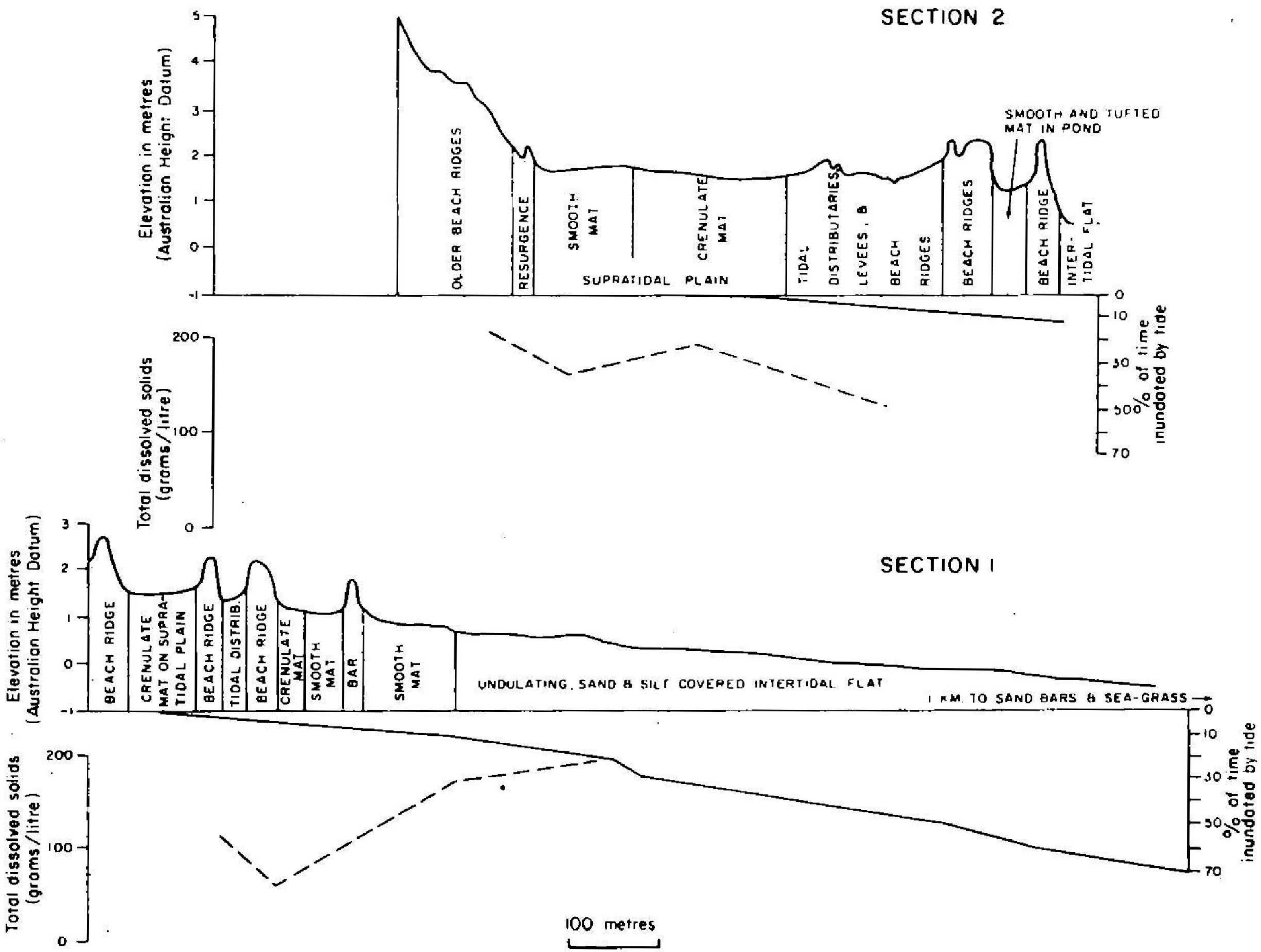


Fig. B3 Depositional environments in the vicinity of Mambray Creek, showing location of sections



Record 1979/61

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Fig. B4 Elevation, environment, tidal inundation frequency, and groundwater salinity along sections 1 and 2 exposed coasts the main beach occurs at higher elevations than on protected shorelines. The areas most favourable for cyanobacterial mat colonisation occur seaward of this protective barrier on exposed coasts, but landward of it on protected coasts, and the latter environment offers a greater opportunity for the preservation of resultant algal-formed facies. An examination of the relationship between elevation inundation, and type of algal mat developed shows that the smooth mat occurs in more frequently inundated areas, and crenulate mat in higher, less frequently inundated locations. Tufted mat occurs in small depressions in the high intertidal zone that are not frequently flooded but retain water for long periods after inundation.

In the supratidal zones of these coastal complexes a study of the inundation relationship shows that the landward margins of the flats are virtually never inundated by the sea. Piezometers were installed across these areas in August using a twin-barrelled corer designed by Tratt, and resulting measurements showed that the water table was only a short distance beneath the surface, even at the higher landward margin of the supratidal zone. We assume that the more steeply sloping and higher landward portion of the supratidal zone is underlain by continental groundwater which has sufficient head to invade this zone. Piezometers installed in the iron pan and carbonate-lithified areas at Fisherman Bay show a positive head, and establish that the diagenesis in these areas is associated with groundwater springs. Gypsum-precipitating springs, analagous to those already known from the Redcliff and Mambray Creek areas, have been discovered at Fisherman Bay. Stable-isotope analyses have been commissioned in order that the studies of the groundwaters may be completed in the coming year.

PRIMARY PRODUCTIVITY IN BLUE-GREEN ALGAL MATS AT SPENCER GULF

by

J. Bauld

STAFF: J. Bauld, C. Manning, M.R. Reed

The objective of the biological studies in Spencer Gulf is to determine the primary biological factors governing sulphur, metal, and carbonate transformations in a modern sedimentary environment.

Since organic carbon supplies the energy requirements for sulphide formation by sulphate-reducing bacteria, particular emphasis is placed on measuring primary productivity (the production of organic carbon by photosynthetic CO_2-fixation) of mat-forming blue-green algae. Extensive blue-green algal mats grow in the high intertidal-supratidal areas at Mambray Creek and Fisherman Bay. Generally the mats consist of thin (1-2 mm) surface layers of living filamentous blue-green algae overlying black zones of active sulphate reduction (see Skyring, below).

Primary productivity is determined experimentally in the field by a radioisotopic method whereby CO_2 is supplied as $^{14}C\text{-}Na_2CO_3$. During each monthly sampling period, time-course experiments were run to check the methodology. In 14 primary productivity time-courses the correlation coefficients calculated for the relationships between $^{14}CO_2$ fixed and time were >0.94. Since the line of best fit passed through, or close to, the origin it was concluded that the samples incubated were essentially unperturbed relative to intact mats and that the measured rates of primary productivity were reasonable estimates of the *in situ* rates.

Analysis of data accumulated during the 12-month period of intensive study of the blue-green algal mats at Mambray Creek is now well advanced. Primary productivities at the three stations studied (4M, 8M, 10M), determined at monthly intervals during the period November 1977-November 1978, are shown in Figure B5. Rates were commonly in the range 100-300 mg C m^{-2} h^{-1} with extremes of 30 and 613 mg C m^{-2} h^{-1}. Primary production tended to be greatest during winter and spring and lowest in the summer months over the period of study.

Field measurements of primary production were routinely made at or near local solar noon. In order to extrapolate from hourly rates, obtained from 2-3 h experiments, to daily rates, measurements were made over the sunrise-sunset period. The data from this experiment are shown in Figure B6. Integration of these data show that multiplying hourly rates by a factor of five enables conversion to daily rates. Daily primary productivity in Mambray Creek intertidal mats was lower than that recorded for hot springs or Solar Lake but comparable to those measured in Antarctic lakes (Table B1). While each of the latter three environments may be considered as extreme with respect to temperature and/or salinity these parameters are, at least, relatively constant. However, in the intertidal environment of Mambray Creek, salinity (50-200 $^{o}/_{oo}$) and diurnal temperature (e.g., 12-48 ^{o}C) variation may be quite substantial.

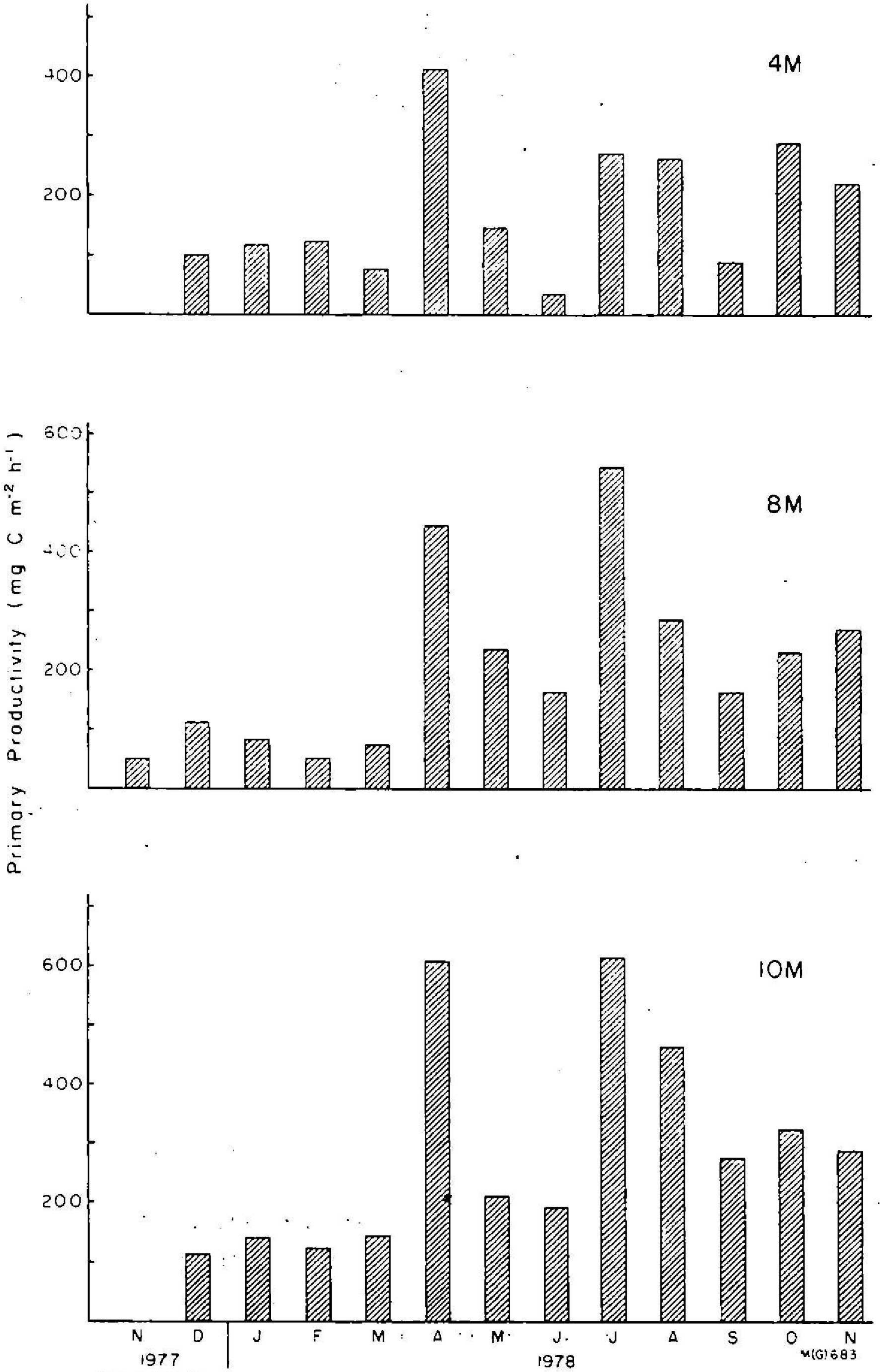

Fig. B5 Monthly determinations of primary productivity for Mambray Creek intertidal blue-green algal mats (smooth) at three stations during the period November 1977 - November 1978

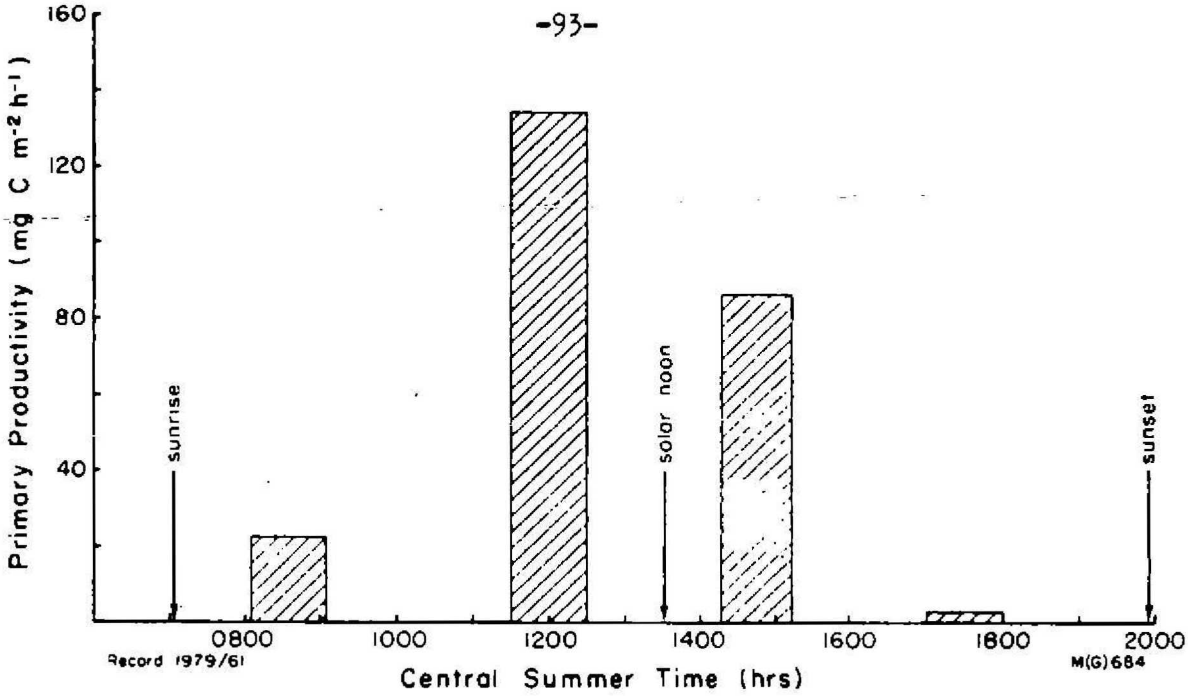

Fig. B6 Smooth mat primary productivity between sunrise and sunset

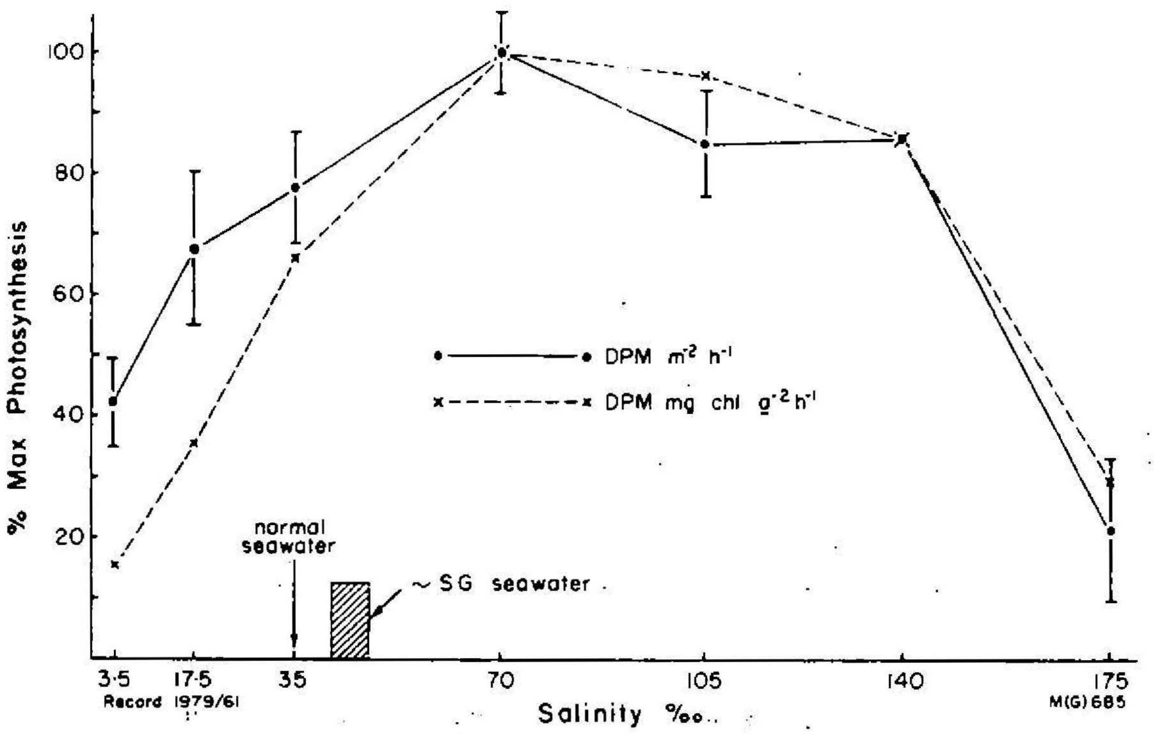

Fig. B7 The effect of salinity on photosynthetic CO_2-fixation by smooth mat

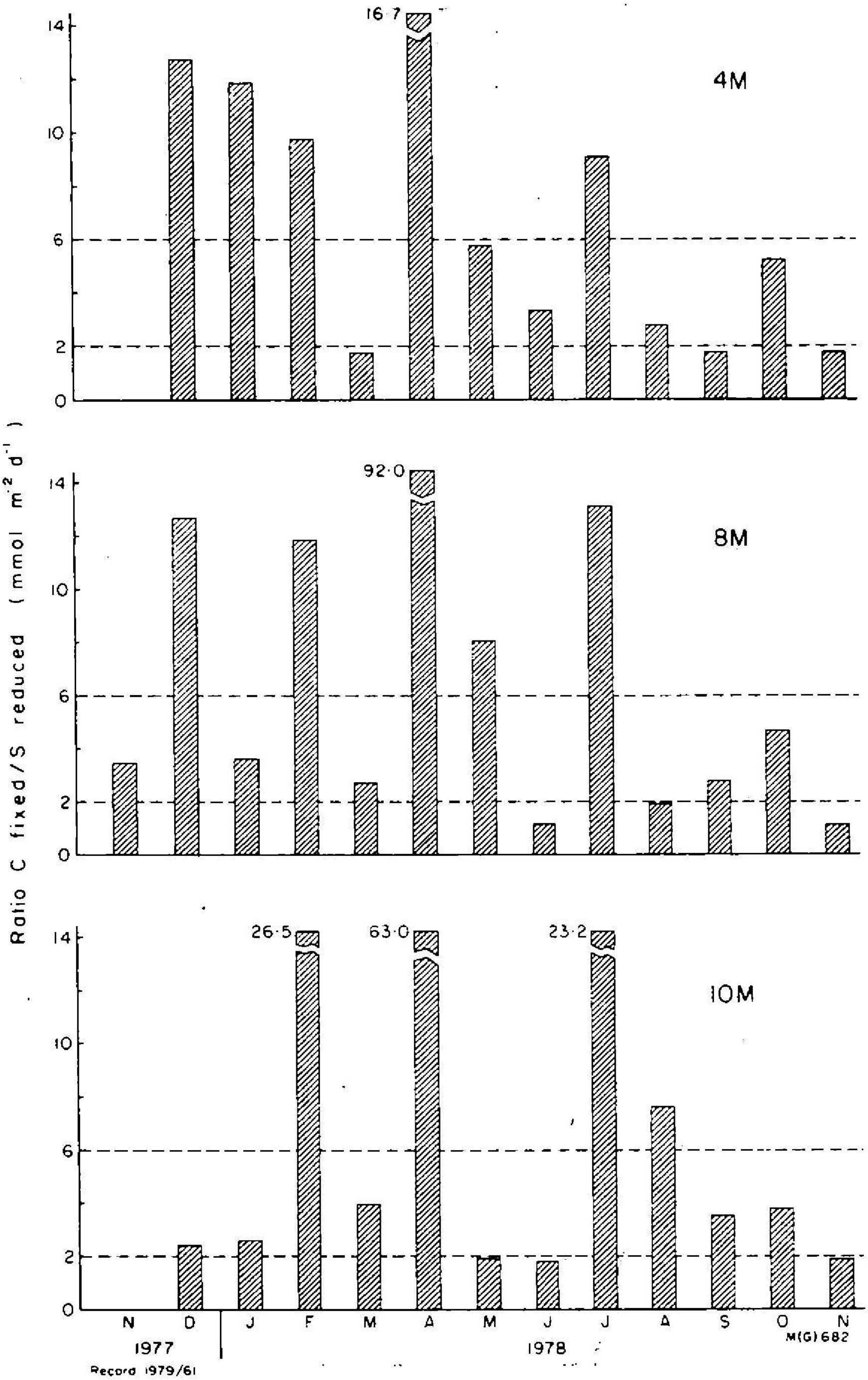

Fig. 88 Molar ratio of carbon fixed (primary productivity) to sulphur reduced (sulphate reduction) derived from contemporaneous measurements in smooth mats at Mambray Creek during the period November 1977 – November 1978

A preliminary experiment indicated that the blue-green algae in the mats were unaffected by salinities up to three times seawater (ca 105 $^{o}/oo$). Further data (Fig. B7), obtained using smooth mat from station 4M, showed that maximum photosynthetic activity occurred at salinities between 70 and 105 $^{o}/oo$. Activity remained high in the range 17.5-140 $^{o}/oo$ and was detectable at 175 $^{o}/oo$ (five times seawater salinity). These results suggest that the blue-green algae are well adapted to the fluctuating salinities which occur during the tidal cycle.

The organic carbon synthesised by primary productivity provides a source of usable carbon for the sulphate-reducing bacteria growing underneath the photosynthesising surface layer. Contemporaneous daily rates of primary productivity and sulphate reduction were compared month by month for each station (Fig. B8). The ratios (moles C: moles S) varied between 1.2 and 92.0. There is both (apparent) undersupply and excess of contemporaneous carbon supply relative to anticipated demand when lactate is assumed to be the substrate oxidised, either partly to acetate (C:S = 6:1) or completely to CO_2 (C:S = 2:1).

Shark Bay

During an excursion to Shark Bay in 1978, radio-isotope experiments were carried out at Hamelin Pool in order to estimate the primary productivity of selected intertidal blue-green algal mats and of subtidal columnar stromatolites. The rates of primary productivity and mat pigment content are shown in Table B2.

The high productivity of colloform mat (113 mg C m^{-2} h^{-1}) reflects the relatively constant nature of the subtidal environment. Unlike colloform mats, the other two stratiform mats occur in the intertidal zone and, in consequence, may be subjected to considerable desiccation stress. Both primary productivity (mg C m^{-2} h^{-1}) and photosynthetic efficiency (mg C mg chl $\underline{a}^{-1}$ h^{-1}) are lower than for colloform mat.

Tufted mat productivity (85 mg C m^{-2} h^{-1}) was greater than that for smooth mat (17 mg C m^{-2} h^{-1}) and reflects its presence in environments where water is retained longer than on smooth mat, which occurs on better

* Chl a = Chlorophyll a, the primary photosynthetic pigment.

drained sediment surfaces. The area of smooth mat sampled was probably exposed to prolonged desiccation before our excursion, since smooth mat in Spencer Gulf has much higher primary production rates.

TABLE B1. PRIMARY PRODUCTIVITY OF BLUE-GREEN ALGAL MATS FROM VARIOUS ENVIRONMENTS

LOCATION	RATE ($g\ C\ m^{-2}\ d^{-1}$)	REFERENCE
Hot spring	7-12	Lenn (1966)
Solar Lake	5-10	Krumbein et al. (1977)
Antarctic lakes	1.6-3.6	Goldman et al. (1972)
Spencer Gulf	0.2-3.1	This paper

TABLE B2. PRIMARY PRODUCTIVITIES AND PIGMENT CONTENT FOR ALGAL MATS IN HAMELIN POOL, SHARK BAY

MAT TYPE	PRIMARY PRODUCTIVITY $mg\ C\ m^{-2}\ h^{-1}$	$mg\ C\ mg\ chl^{-1}\ h^{-1}$	CHL *a* content ($\bar{x} \pm s$, n=8) $mg\ m^{-2}$	$mg\ g^{-1}$ protein
<u>Intertidal mats</u>				
Smooth (STN 6)	17	0.24	124 ± 23	3.27 ± 0.88
Tufted	85	0.16	714 ± 170	18.60 ± 4.78
Pustular (STN 5)	nd	9.12	nd	$(1.80 \pm 0.50)\times10^{-3}$
<u>Subtidal mats</u>**				
Colloform	113	2.25	92 ± 34	2.34 ± 0.80
Internal	nd	1.00	nd	$(1.10 \pm 0.41)\times10^{-3}$

nd not determined

* Chl *a* = chlorophyll *a*

** from subtidal stromatolite column. Colloform is surface mat: intertidal mat is of gelatinous, resilient consistency.

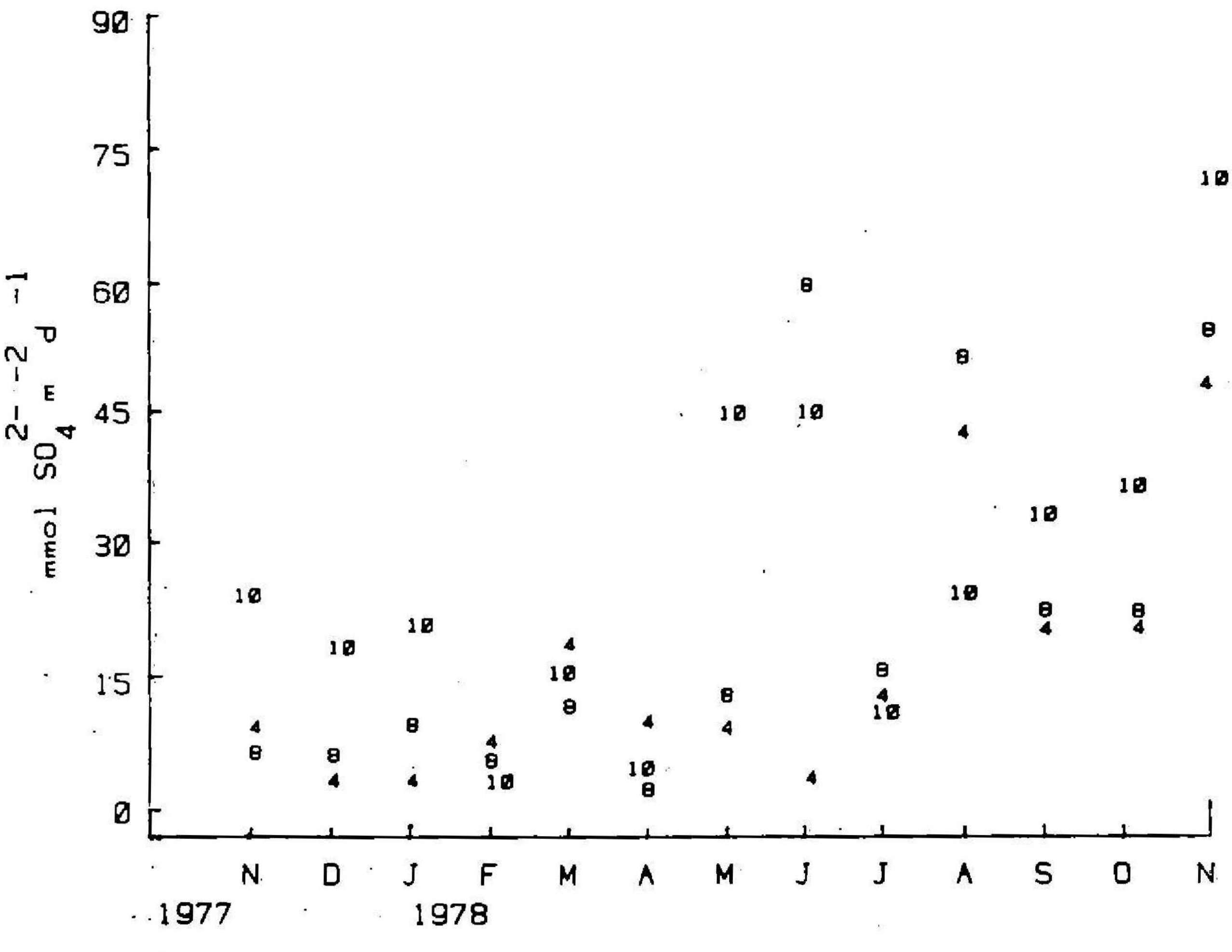

Fig. B9 The sulphate reduction rates in algal mat sediments from Mambray Creek at Stations 4M, 8M and 10M. Data points for the Stations are represented by the numbers 4, 8 and 10 respectively

SULPHATE REDUCTION IN ALGAL MAT SEDIMENTS

by

G.W. Skyring

STAFF: I.A. Johns, L.A. Plumb, M.R. Reed, M. Thomas, G.W. Skyring

The patterns of sulphate reduction rates in intertidal sediments for Mambray Creek for the period from November 1977 to November 1978 are given in Figure B9. The simpler statistical analyses are complete, and the more important aspects of the results are discussed below.

The sulphate reduction rates (mmol SO_4^{2-} m^{-2} d^{-1}) at station 10M(29 ± 2.5) was significantly greater (p=0.000) than those at station 8M(19 ± 2.5) and 4M(14.5 ± 2.1). At all stations, the sulphate reduction rates from May to December 1978 were generally higher than those during November 1977 to April 1978. Generally, the sulphide contents (umol g^{-1}) of the mat-associated sediments were less variable from month to month; however, the sulphide content of station 4M(9 ± 1) was significantly lower than those of stations 8M(31.6 ± 1.5) and 10M(25.5 ± 1.3).

Frequency distribution analyses of small and larger (pooled) sets of data showed that the sulphide contents appeared to have a near normal distribution, whereas the distribution of sulphate reduction rates was skewed to the left (Fig. B10). This suggests that the sites of lower sulphate reduction activity are predominant, and that the overall fixation of sulphide in the sediments is not solely controlled by the rate of reduction. These results, however, will need to be examined more rigorously.

The relationships between sulphate reduction rates, and environmental/ climatic factors are complex. The most obvious was a significantly linear correlation between sulphate reduction rate and porewater salinity. Because of the more dominant effect of salinity, the effects of seasonal temperatures were not immediately obvious. However, a multiple regression analysis of the pooled data showed that there was a significant temperature effect on sulphate reduction rate. In a more direct study, data from an experiment in which samples were incubated at 10, 20, 30, and 40°C, showed that at constant porewater salinity the relationship between the sulphate reduction rate and the temperature (Fig. B11) was consistent with the Arrhenius equation:

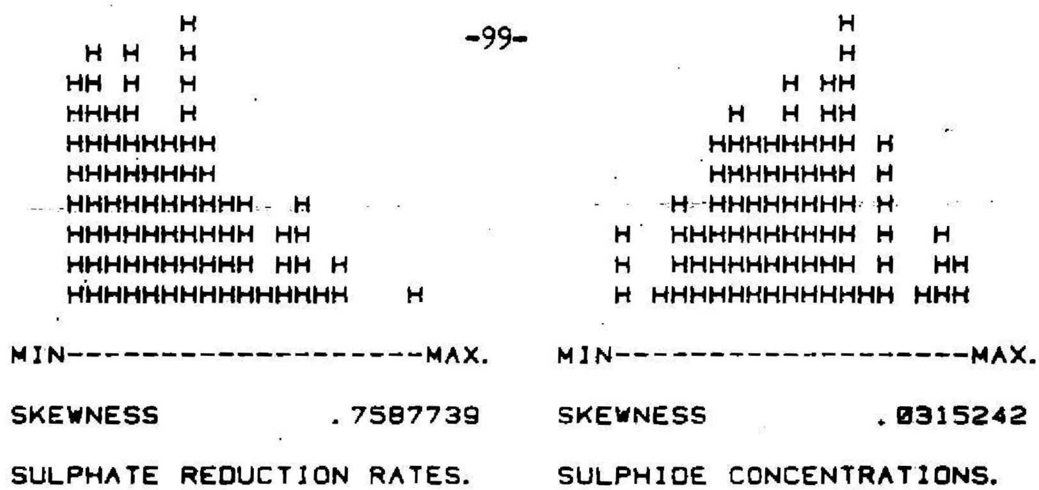

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Fig. B10 The frequency distribution of all sulphate reduction rates and sulphide concentrations for algal mat sediments from Station 10 M

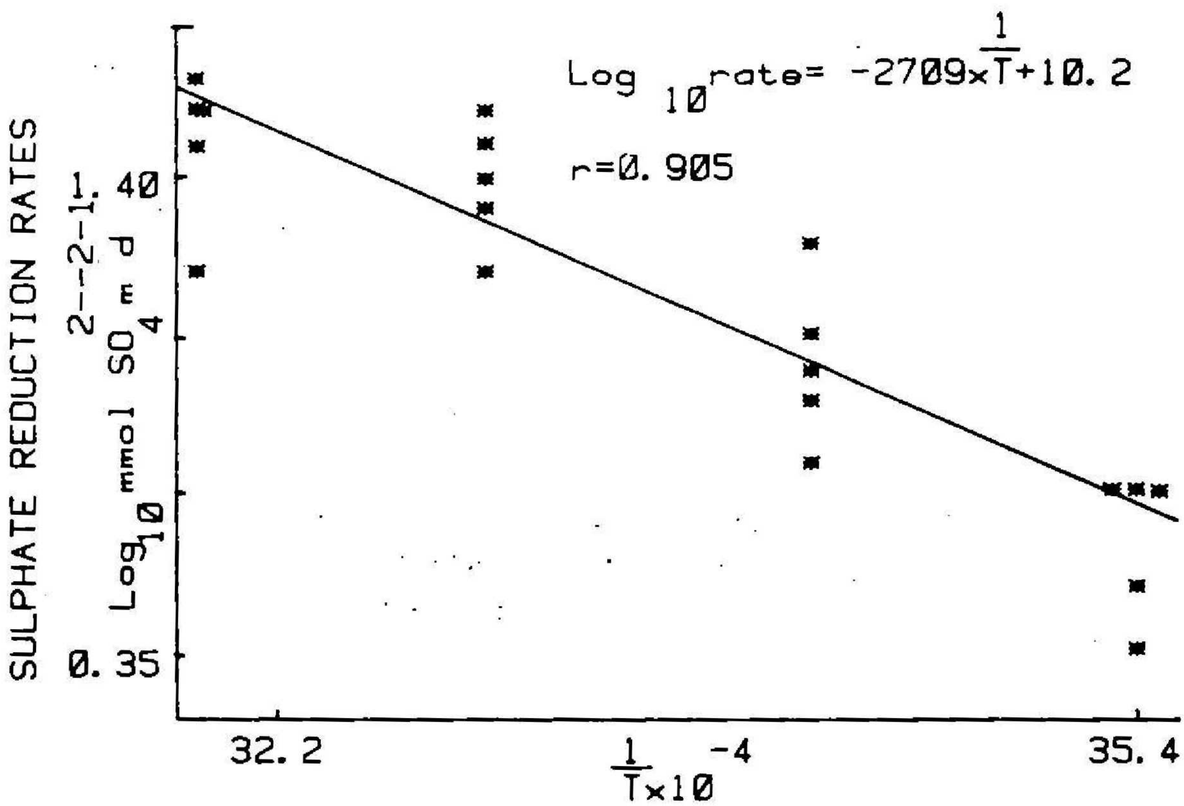

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Fig. B11 The relationship between the reciprocal of the absolute temperature and $\log_{10}$ sulphate rate in Mambray Creek algal mat sediments

$$\log_{10} \text{rate} = -\frac{\Delta H}{2.303RT} + C$$ (where ΔH = activation energy, R = gas constant, T = absolute temperature, and C is a constant).

The methodology for assessing sulphate reduction rates was checked at each monthly sampling period by running time course experiments. If there was a significant linear correlation between the periods of incubation and sulphate reduced, and the line of best fit passed through or close to the origin, it was concluded that the samples were minimally perturbed. The correlation between sulphate reduced and time was significant (p = 0.2 to 0.01) and the average of the intercepts for 12 separate experiments was 11 minutes. Thus the methods appeared reliable and the measured rates were probably reasonable estimates of those which occurred in situ.

The sulphate reduction rates shown in Figure B9 were those occurring in algal mat sediments collected at the time of maximum tidal inundation. Figure B12 shows the variation in sulphate reduction rates during an inundation cycle. Maximum rates of sulphate reduction occurred two days after maximum inundation.

The statistical analyses of the collected data are continuing and will be used to compute annual sulphate reduction rates that may be expected under various environmental conditions. It will then be possible to examine quantitatively the feasibility of extant models of biogenic sulphide ore formation.

SULPHUR ISOTOPE FRACTIONATION IN MARINE ENVIRONMENTS

by

P.A. Trudinger

STAFF: L.A. Plumb, M. Thomas, P.A. Trudinger

Studies are in progress to establish the sulphur isotope patterns characteristic of particular marine sediments and, where possible, to relate these patterns to the geochemistry, biology, and sedimentology of the sediments.

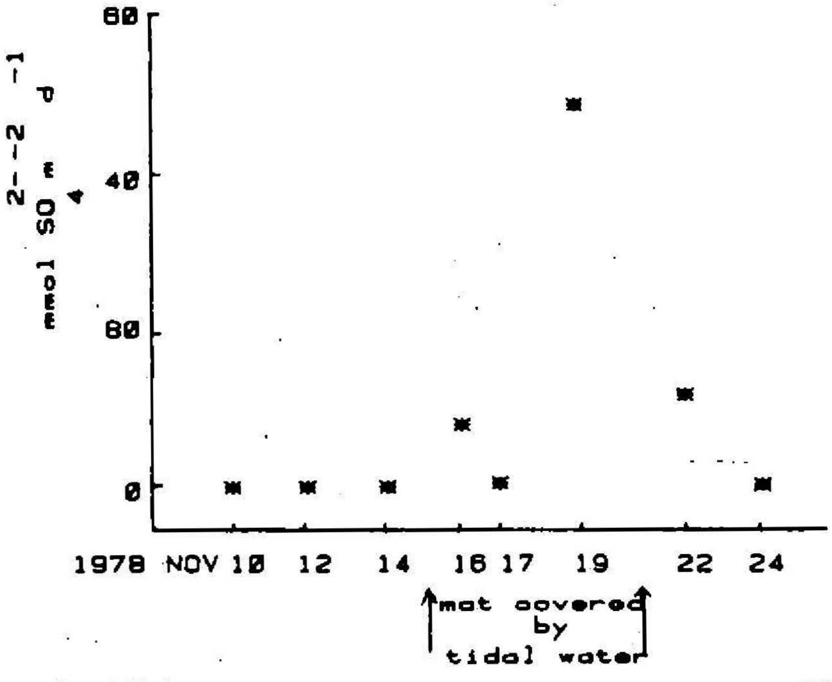

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Fig. B12 The sulphate reduction rates in algal mat sediments, before, during and after tidal inundation

Mambray Creek

Table B3 lists data for the content and isotopic composition ($\delta^{34}S$) of sulphide in the upper 2 cm of Mambray Creek sediments where most (>90%) of the sulphate reduction activity occurs. Also listed are the expected monthly increments in sulphide content calculated from the observed rates of sulphate reduction and assuming that all sulphide formed would be fixed in the sediments.

It is clear from the results that very little sulphide is preserved. This is reflected in the changes in $\delta^{34}S$ values for month to month which indicate a fairly rapid turnover of sulphide. Whether the losses of sulphide are due to reoxidation or diffusion to the atmosphere (or both) remains to be determined. There is preliminary evidence for the presence of elemental sulphur in the sediments.

$\delta^{34}S$ values of Mambray Creek sulphides showed significant negative correlations (ρ=0.01 to 0.1), with the mean monthly temperature (Fig. B13). This result agrees with those of earlier laboratory experiments which established that increases in temperature cause decreases in isotopic fractionation by accelerating the rates of sulphate reduction per organism.

Spencer Gulf sediments

Isotope and geochemical data from offshore vibrocore samples have been assessed. Although the isotope values are characteristically 'biogenic', there is a novel pattern of distribution which indicates that anaerobic conditions are only very recent and that the principal activity is within the sediment rather than at the sediment-water interface. Pyrite (zinc-reducible sulphide) represents no more than 50% of the total sulphide, and this may indicate a formation mechanism involving elemental sulphur.

Bali Trough

Through the courtesy of the Woods Hole Oceanographic Institution we obtained several cores collected during the cruise of Atlantic II from Darwin to Singapore in 1976. Of these, a core (No. 39) from the extension of the Java fore-arc basin (water depth 3500 m), consisting of extremely fine-grained clay

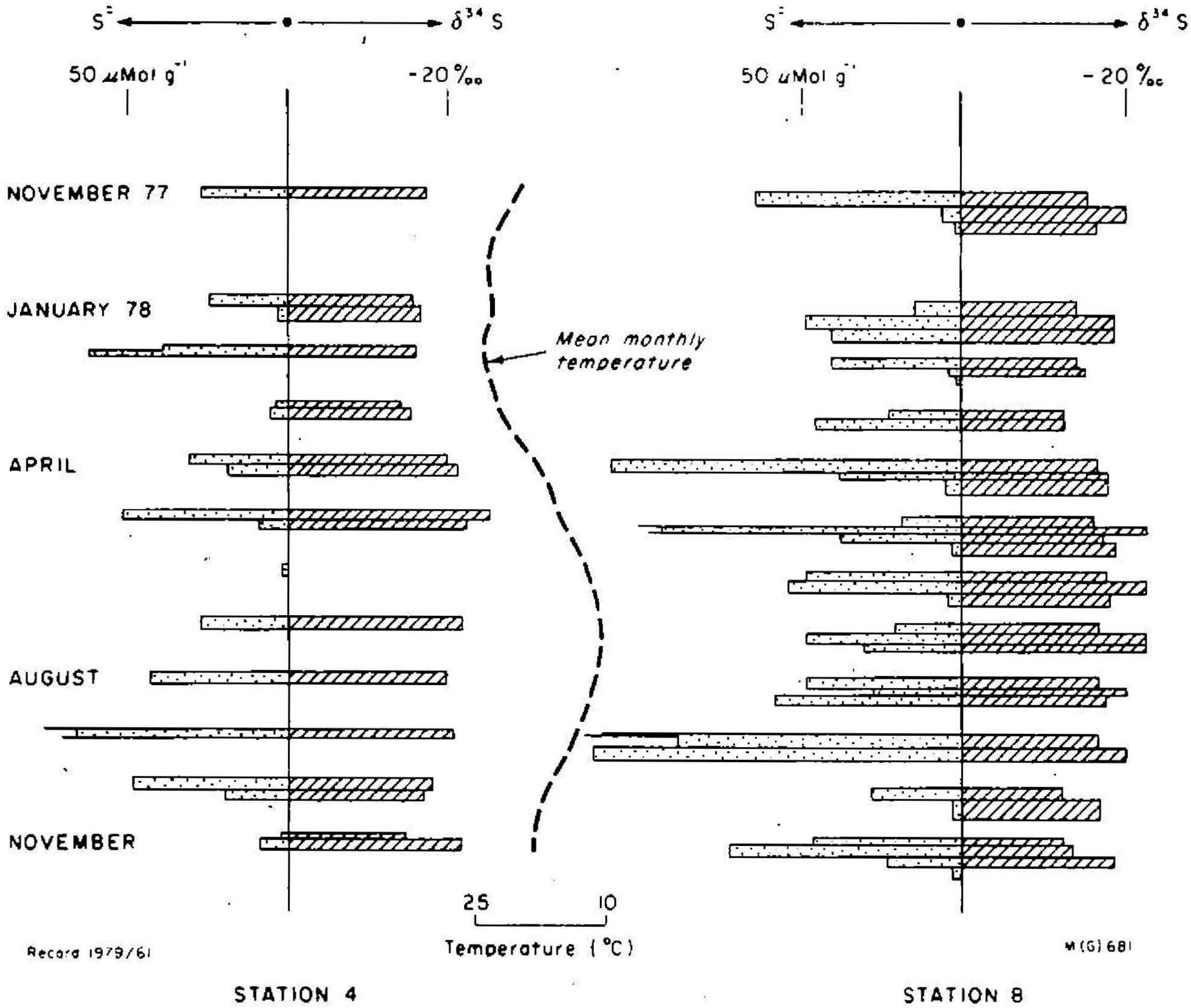

Fig. B13 Sulphide concentration and isotopic composition in sectioned 5cm sediment cores from Mambray Creek related to mean monthly temperatures between November 1977 and November 1978

TABLE B3

ISOTOPIC COMPOSITION OF SULPHIDE IN THE UPPER 2cm OF SEDIMENT (MAMBRAY CREEK)

STATION	DATE	SULPHIDE µ mol g^{-1} TOTAL	SULPHIDE µ mol g^{-1} CALCULATED INCREMENT	$\delta^{34}S$ ‰
M4	Nov. 77	26		-17.2
	Jan. 78	25	19	-15.1
	Feb. 78	27	3	-15.9
	Mar. 78	5	10	-14.3
	Apr. 78	23	12	-20.5
	May. 78	31	19	-24.1
	Jun. 78	1	16	
	Jul. 78	25	6	-21.5
	Aug. 78	43	17	-19.6
	Sept. 78	26	25	-20.4
	Oct. 78	40	18	-17.4
	Nov. 78	4	59	-19.7
			204	
M8	Nov. 77	63		-15.7
	Jan. 78	14	21	-14.4
	Feb. 78	29	14	-14.1
	Mar. 78	37	13	-12.7
	Apr. 78	62	7	-18.1
	May 78	50	6	-21.4
	Jun. 78	49	34	-19.1
	Jul. 78	20	33	-16.8
	Aug. 78	46	31	-17.6
	Sept. 78	50	41	-17.8
	Oct. 78	56	22	-13.1
	Nov. 78	56	117	-14.0
			339	
M10	Nov. 77	61		-16
	Jan. 78	66	56	-16.6
	Feb. 78	12	12	-9.1
	Mar. 78	52	9	-15.0
	Apr. 78	70	9	-19.3
	May 78	58	24	-19
	Jun. 78	21	43	-18
	Jul. 78	23	26	-18.4
	Aug. 78	39	11	-17.2
	Sept. 78	66	24	-16.9
	Oct. 78	26	33	-20
	Nov. 78	39	69	-17.2
			316	

sediments, showed evidence of vigorous sulphate reduction below the sediment-water interface: pore water alkalinity was high and sulphate was greatly depleted (90-100%).

An analysis of the sulphur isotope distribution in core 39 has been carried out to complement geochemical studies being conducted by Dr. P.J. Cook of the Australian National University. $\delta^{34}S$ values for total sulphide ranged from -25 to +15 $^{o}/oo$ and there was a well defined trend towards increasing enrichment in ^{32}S with depth over the first 700 cm of core (Fig. B14). This general trend is similar to that observed in the sulphides on the Kupferschiefer deposit in Westfallen, Germany, and in the pyrite of the Pb-Zn deposit at McArthur River, Northern Territory.

Possible explanations for this isotopic pattern will be examined when all geochemical and sedimentological evidence is to hand.

RECENT SUPRATIDAL CARBONATE LITHIFICATION AND ITS RELATION TO THE CHEMISTRY AND HYDROLOGY OF PRESENT-DAY GROUNDWATER ACTIVITY, FISHERMAN BAY, SA

by

James Ferguson

STAFF: R.V. Burne, James Ferguson, D. Fitzsimmons, L.A. Plumb

The lithification of unconsolidated carbonate sediments in near-surface,subaerial environments has been proposed as a major process in the formation of limestones. Consequently, the products of carbonate diagenesis of this type have been extensively documented in terms of the mineralogical and textural evolution of the carbonates and to a lesser extent their trace element geochemistry. Less well established, however, is the relationship of these parameters to the chemical, hydrological, and sedimentological characteristics of the original environment of carbonate lithification. This situation arises partly because of a lack of suitable modern environments where theoretical and experimental predictions of the relationships of groundwater to carbonate composition can be tested.

At Fisherman Bay, SA, marine carbonate sediments in the high supratidal zone are being lithified under conditions where changes in groundwater chemistry can be related to specific mineralogical and textural changes in the original carbonate sands, with greater than normal certainty. The present project is

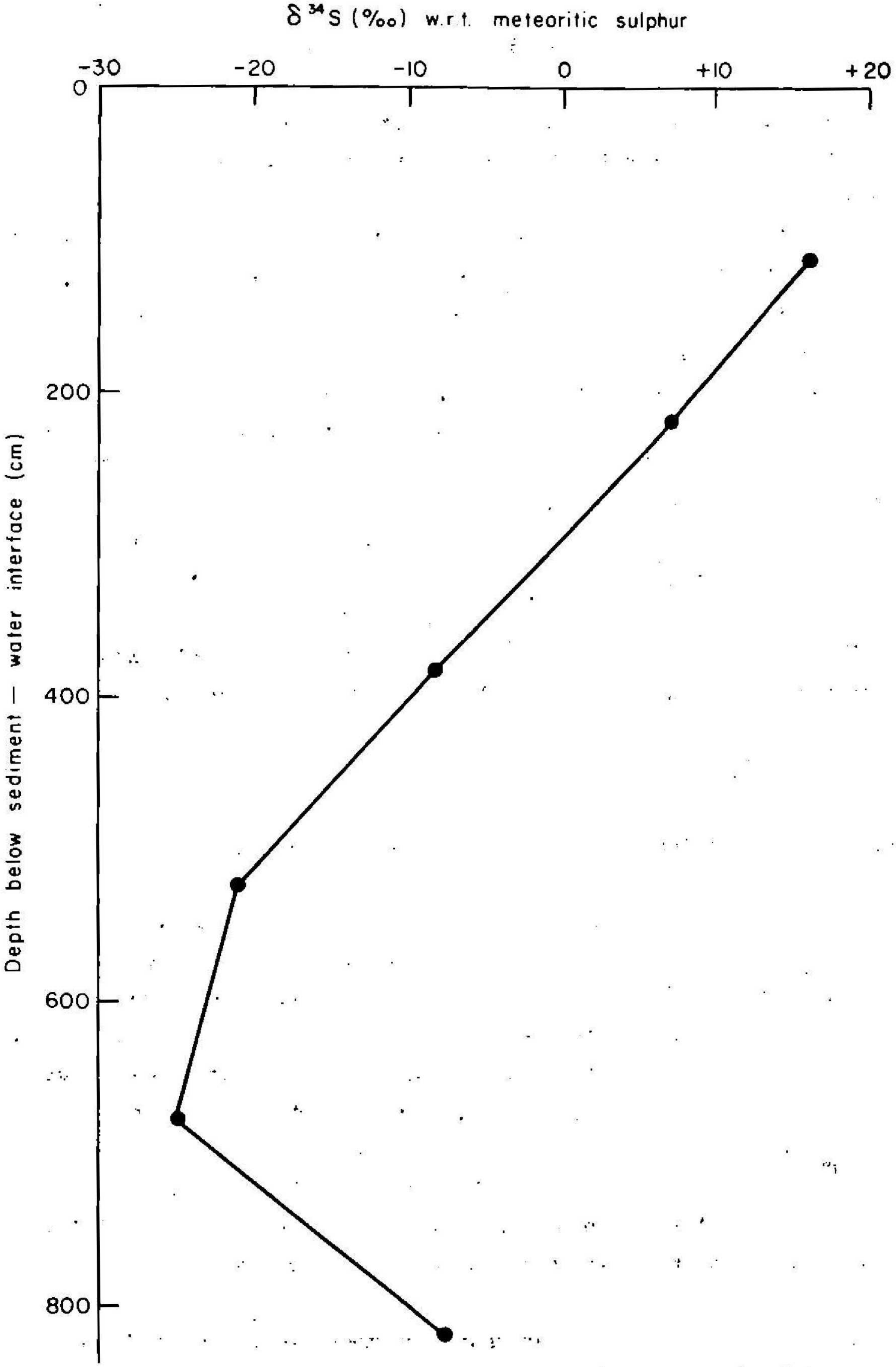

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Fig. B14 Variation with depth of isotopic composition of sulphides in Bali Trough sediments designed to compare these relationships to theoretical and experimental predictions and to compare and contrast the characteristics of the lithified carbonates with those formed in more arid sea-water-dominated coastal environments.

The study area is one of a group of three areas of active carbonate lithification in the high intertidal/supratidal zone of a prograding, paralic sediment complex on the northeast shore of Fisherman Bay (Fig. B15).

At the surface the carbonate lithification appears as two concentric zones (Fig. B16) - an outer 'pavement' showing little surface relief and an inner, more extensive area, characterized by 'teepee' structures and polygonal cracks, with associated carbonate and gypsum deposits. In cross-section (Fig. B16) the 'pavement' appears to comprise mainly 'blocky' poorly laminated carbonate whose thickness and degree of lithification decreases progressively towards the outer edge of the area. The central area is lens-shaped and comprises strongly laminated carbonates fused together to form a hard, cellular, continuous crust. At the outer fringes this crust overlies blocky carbonate, but in the central areas the underlying carbonate sand contains numerous semi-lithified thin carbonate discs which are obviously precursors of the laminated crust.

The inner carbonate crust is relatively hard and continuous, and extends over a considerable area - characteristics which have led to extensive fracturing, probably by thermal expansion and contraction. The polygonal cracks are sites where underlying groundwaters can emerge at the surface, either directly in the area of maximum groundwater head, or by capillary evaporation at other sites. The result is a secondary aragonite/gypsum or aragonite deposit on or at the edges of the fractures. Teepee structures are more complex and most seem to have formed water-filled cavities which are sites for extensive secondary aragonite and gypsum precipitation, and possibly for the activities of iron and manganese-oxidising bacteria. As a result the cavity sediments are ofen stained bright red and/or black by precipitated Fe(III)-and Mn (IV)-oxides, which are also incorporated into aragonite/gypsum precipitates forming red or black banded stalactites, stalagmites, and pisoliths.

Groundwater in the lithified zone is discharged from a pressure aquifer in Tertiary carbonate sands and gravels. Usually this aquifer underlies the unconfined water table aquifer, which in turn is associated with surface aeolian sands and an underlying relatively impermeable clay horizon. A drill-hole in

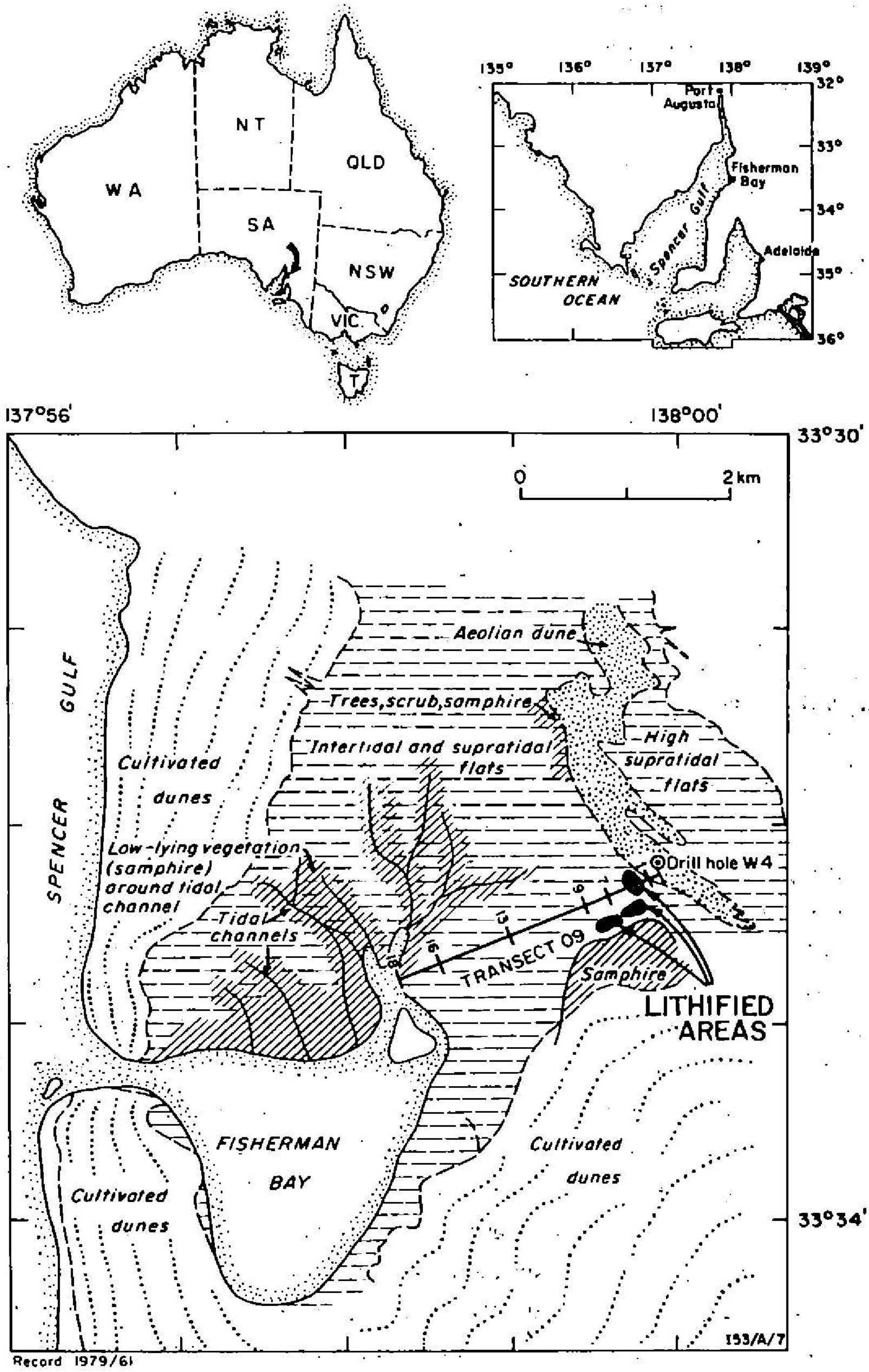


Fig. B15 Location of areas of carbonate lithification at Fisherman Bay, Spencer Gulf, South Australia

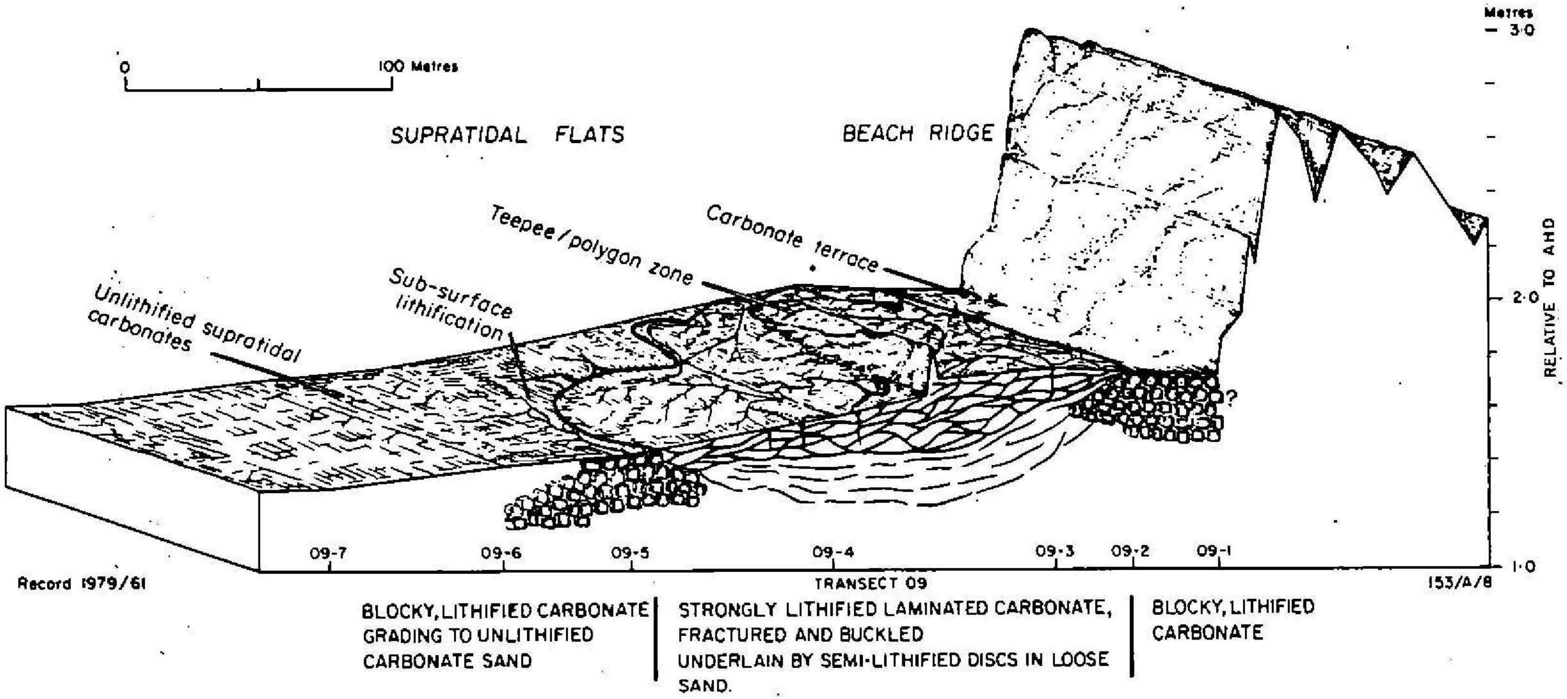


Fig. B16 Major zones of carbonate lithification associated with groundwater springs at Fisherman Bay the sand dune behind the lithified zone encountered a much thinner clay sequence than normal, which suggests that outcropping of the pressure aquifer may be related to local thinning of the confining clay layers. The groundwater discharge controls the level of the water table within the lithified zone and for a distance of some 200 m seaward, at which point mixing with marine-derived brines becomes evident. As the ground elevation in these areas is controlled by aeolian deflation to the capillary wetting zone, this zone of mixing is marked by a change in slope of the intertidal plain. In winter the water table at the spring source is high enough for water to be discharged onto the sediment surface. The water level declines rapidly with distance, however, and at the outer edge of the lithified zone it coincides with the level, within the sediments, where lithification is occurring at the present day.

Compared to sea water, the spring waters have similar total dissolved solids, but lower pH values and high Ca, alkalinity, and CO_2 concentrations. Consequently, when they reach the near-surface environment the initial reaction is loss of CO_2 and precipitation of carbonate phases, followed, as evaporation proceeds, by gypsum precipitation. In the central zone the laminated crust inhibits evaporation and slows down the loss of CO_2, leading to relatively small degrees of supersaturation of the groundwaters with respect to carbonate phases. Lithification, therefore, proceeds initially in the most favourable horizons with the consequent development of lithified laminae. As these laminae coalesce, they form a continuous network protecting the sediment in the 'cells' from subsequent lithification. At the edge of the lithified area the surface crust is absent and loss of CO_2 and evaporation in the capillary wetting zone proceed relatively rapidly. Lithification is thus more general and poorly laminated, blocky carbonates are formed.

ORE GENESIS INVESTIGATIONS

The general aim of the ore genesis studies is to determine the origin of various stratabound base-metal sulphide mineral deposits and to ascertain which characteristics of the deposits could, in the future, serve as exploration guides.

STUDIES IN ADELAIDE GEOSYNCLINE AND STUART SHELF

by

T.H. Donnelly

STAFF: T.H. Donnelly, J. Knutson, I.B. Lambert, P.M. Ryan

The objective of this study is to provide information relevant to consideration of ore genesis and exploration guides through isotopic, geochemical, and petrologic studies of mineralised and unmineralised sequences in the Stuart Shelf and Adelaide Geosyncline (Fig. B17).

1. Stuart Shelf

The following is a discussion of some of our results on samples from the Mount Gunson/Lake Dutton areas.

The main emphasis of our investigations has been on the Cu-Pb-Zn mineralisation in the Proterozoic Pandurra Sandstone and Tapley Hill Formation. The sandstone sulphide mineralisation, as typified by the Cattle Grid copper deposit, is epigenetic, having formed after exposure, weathering, and brecciation of the Pandurra Sandstone surface. This contrasts with mineralisation in the younger Tapley Hill Formation in which the original iron sulphides were apparently syngenetic or early diagenetic. Textural evidence indicates that subsequent replacement of iron sulphides by Cu-Fe sulphides also occurred early in the diagenetic history of the Formation before complete lithification.

The Tapley Hill Formation has minor enrichment in Cu, Pb, and Zn throughout, compared with average values for similar rocks. However, where there is marked enrichment there is a zonation from Cu to Pb and Zn inward from both the upper and lower surfaces of the stratigraphic unit. This indicates that where these base metals are strongly enriched they have been introduced along permeable zones after deposition of the Tapley Hill Formation. There is abundant evidence indicating the Adelaidean Stuart Shelf rocks were deposited in fluviatile, deltaic, and shallow-marginal-marine environments, the latter including alluvial fans, evaporative mudflats, and ephemeral lakes. Desiccation features and the presence of evaporitic minerals indicate an arid climate; algal structures indicate biological activity; and syngenetic/early diagenetic pyrite indicates reducing conditions.

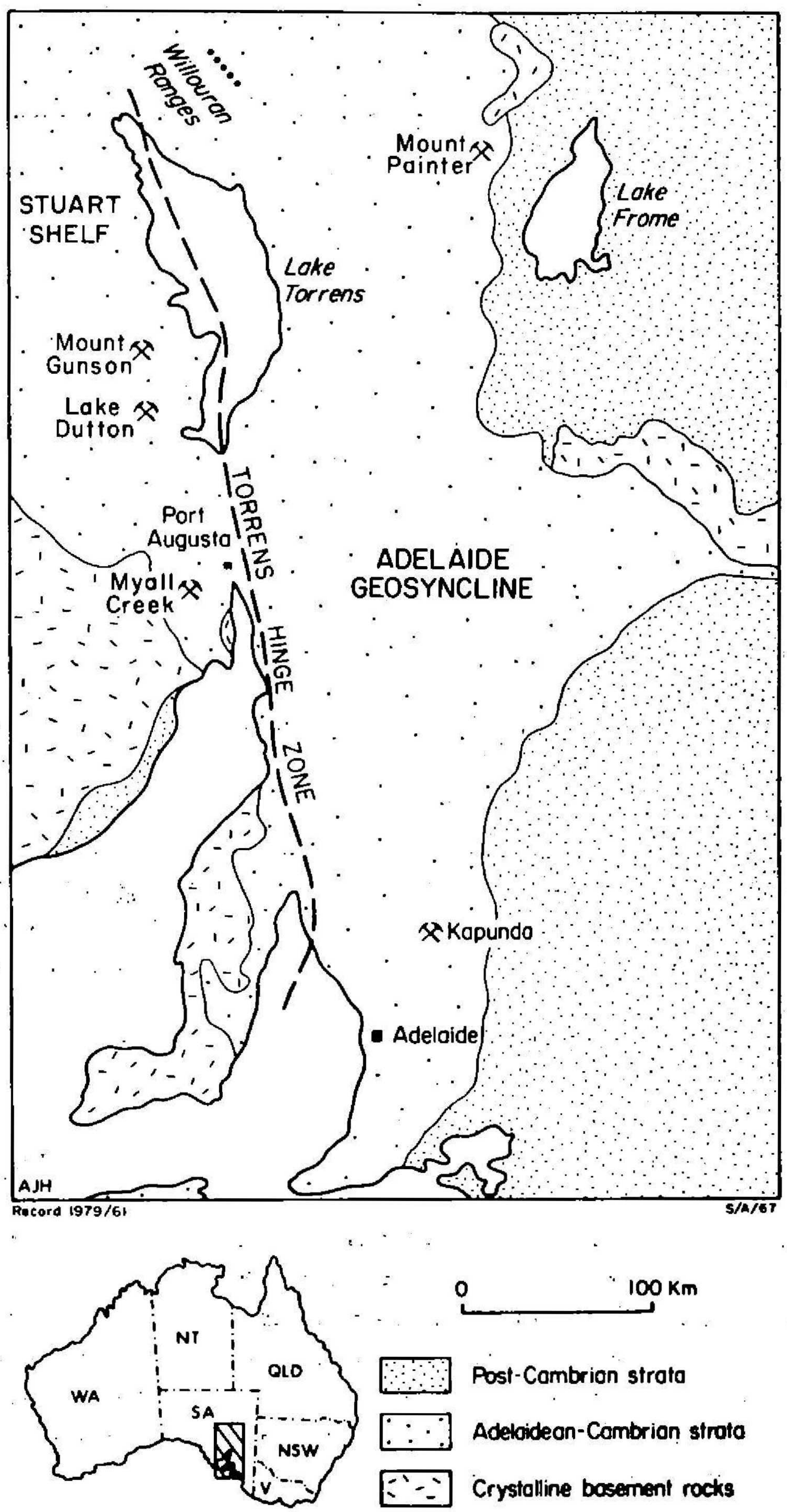


Fig. B17 Sketch map showing locality of the copper-rich areas under investigation and major geological features of southern South Australia

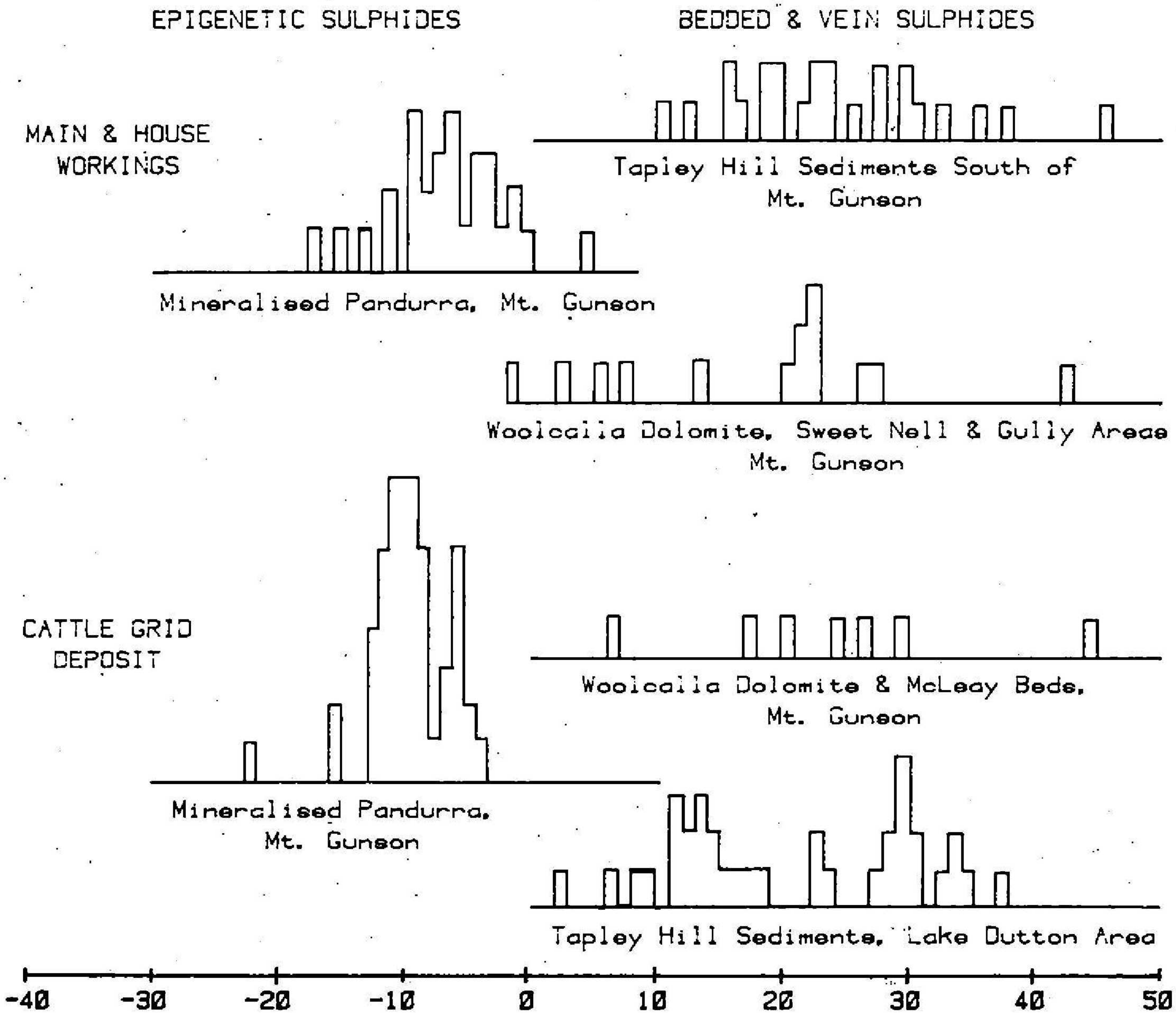
Initial analytical work on carbonate minerals indicates that variations in composition generally result from the substitution of Fe and Mn for Mg, while Ca content remains relatively constant. Generally fine-grained micritic carbonate shows less variation in composition than more coarsely crystalline carbonate, and coarse carbonate associated with sulphide mineralisation is enriched in Fe and Mn. Pure calcium carbonate appears to be restricted to carbonate replacing gypsum in the evaporite lenses of the Tapley Hill Formation.

Preliminary statistical analysis of the chemical data (>100 samples) suggests there is no correlation between Cu, Pb, and Zn where these metals are present in background quantities only. However, in rocks showing enrichment in these metals some correlation is apparent.

Chemical analyses of rocks from the Tapley Hill Formation indicate that these rocks contain significant contributions from a basic igneous source. However, initial statistical data suggest that Cu, Pb, and Zn enrichment results from factors other than direct derivation from this igneous material.

There is a good correlation ($r = +0.72$) between organic carbon (C_{org}) and total sulphur (SO_3) in the Tapley Hill Formation. Correlation coefficients for iron versus SO_3 and C_{org} are +0.72 and +0.39, respectively, and those for MgO versus SO_3 and C_{org} are -0.39 and -0.44, respectively. Iron has moderately good correlation with TiO_2 and Al_2O_3 (r = +0.72 and +0.60, respectively), but no correlation with CO_2. MgO has negative correlation with TiO_2 and Al_2O_3 (r = -0.81 and -0.92, respectively) and a good positive correlation with CO_2 ($r = +0.97$). These results indicate that the bulk of the iron was originally concentrated in detrital silicate and oxide fractions of the sediments, whereas MgO was largely restricted to the carbonate fraction. There is no apparent correlation between Cu and SO_3, whereas for FeO versus SO_3, $r = +0.53$. In most instances correlations improve when values are determined for the silt-rich rocks only and dolomites are omitted.

Sulphur isotopic compositions of epigenetic copper from the presently operating open-cut mine (Cattle Grid) and previously worked mines (Main and House Workings) are shown contrasted with syngenetic sulphides in the Tapley Hill sediments in Figure B18. The markedly positive $\delta^{34}S$ values for the younger Tapley Hill sulphides precludes them as a potential sulphur source for the formation of the copper ore in the underlying Pandurra Quartzite. This was one possible model as, in the vicinity of the mine areas, the younger sequences



Record 1979/61

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Fig. B18 Sulphur isotopic compositions of the epigenetic copper ore at Cattle Grid, Main and House Workings (av. $\delta^{34}S \approx -7‰$) contrasted to the syngenetic sulphides from Tapley Hill (av. $\delta^{34}S \approx +20\%$)

have been removed by erosion, leaving a disconformity surface between the Pandurra and overlying Whyalla Sandstone. The mineralisation roughly follows the interface between these units and occurs in fractures, vugs, and along bedding planes.

So far no sulphate minerals have been found that can be related to the sulphide mineralisation in Tapley Hill Sediments. The sulphates are best explained as having formed from younger (Recent) sulphate-containing waters. Carbonates in dolomitic siltstones and dolomitic sandstones from drill cores of the Tapley Hill sedimentary rocks in the Lake Dutton area have both carbon and oxygen isotopic compositions typical for unaltered marine carbonates of Precambrian (Adelaidean) age. The fact that both $\delta^{13}C$ and $\delta^{18}O$ values are compatible with normal marine carbonates suggests the basin(s) in which Tapley Hill sediments were laid down was depleted only in sulphate.

2. Adelaide Geosyncline

(i) Kapunda:

Chalcopyrite-rich bedded and vein mineralisation at Kapunda occurs in two locally developed dolosiltstone units within a sequence of generally darker-coloured, finer-grained calcmudstones and siltstones. The Mine Series accumulated in shallow-water to supratidal, sabkha-like environments; there is no evidence for igneous activity in the region. Isotope data for bedded sulphides are characteristic of biological sulphate reduction in a restricted basin. It is likely that iron sulphides were produced initially, and that copper was introduced subsequently in mildly oxidising, highly saline groundwaters, whose influence is seen in the low temperature oxidation of organic matter in the ore-zones. Calcite is converted to dolomite in the mineralised siltstone with $\delta^{13}C$ and $\delta^{18}O$ values significantly different to the host calcite. Isotopic data support derivation of the vein mineralisation from their host sediments (Fig. B19), and this appears to have occurred before lithification.

(ii) Mount Painter:

This is essentially an isotopic study of the Cu-U mineralisation, being carried out in cooperation with geologists from the South Australian Department of Mines. Only some very preliminary investigations have been carried out so

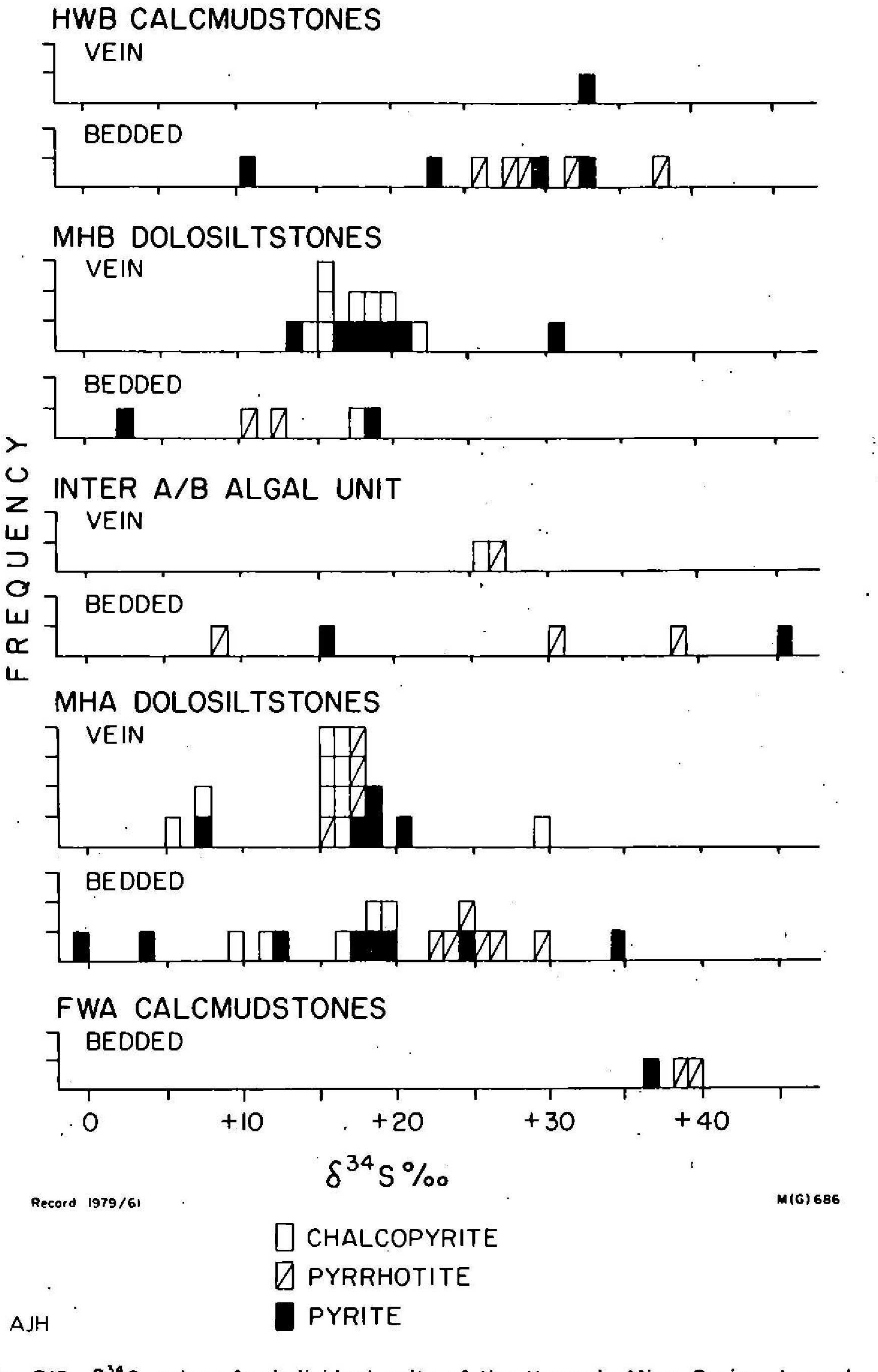


Fig. B19 $\delta^{34}S$ values for individual units of the Kapunda Mine Series. In each case the vein sulphides have similar values to bedded sulphides in in their host unit. Note the tendency for cyclicity of $\delta^{34}S$ values, with the most positive values occurring in the mineralised units below, between and above MHA and MHB Dolosiltstones far and these indicate that the processes forming this deposit were probably magmatic. This contrasts with the absence of magmatic influences noted for Cu mineralisation in the other areas of the Adelaide Geosyncline and Stuart Shelf.

ISOTOPE STUDIES IN THE PINE CREEK GEOSYNCLINE, NT

by

T.H. Donnelly

STAFF: T.H. Donnelly (in collaboration with John Ferguson, G. Ewers, and D. Tucker, BMR)

Objectives: (i) To investigate the genesis of uranium mineralisation in the Alligator Rivers Region, NT (Fig. B20).

(ii) To investigate the genesis of base metal mineralisation in the Rum Jungle area.

(iii) To examine the antiquity of sulphate reducers, from the isotopic compositions of ancient sedimentary sulphides formed in reducing environments.

(iv) To examine the $\delta^{34}S$ values of sulphides in the lowermost stratigraphic units of the Pine Creek Geosyncline, and to test their applicability as stratigraphic indicators.

The isotope study of three major Lower Proterozoic stratabound uranium deposits (Jabiluka 1 and 2, Ranger 1, and Koongarra) has been completed. As well, with separate studies by John Ferguson and G. Ewers the isotope results have been integrated into a paper on the development of uranium mineralisation in the region.

The uranium orebodies have a number of features in common; these are (i) their occurrence within the lower part of the Cahill Formation, (ii) location within organic-rich breccia zones, (iii) subjection to low-temperature retrogressive metamorphism, (iv) close juxtaposition to granitoids, and (v) occurrence near the Lower-Middle Proterozoic unconformity. The deposits are also characterised by their occurrence in carbonate-rich areas, but carbonate is either absent or nearly absent within the ore zones.

The Lower Proterozoic sediments are anomalously enriched in uranium, having been derived from an Archaean provenance containing granitoids with 2-6 times normal uranium abundance. The uranium has been further concentrated into

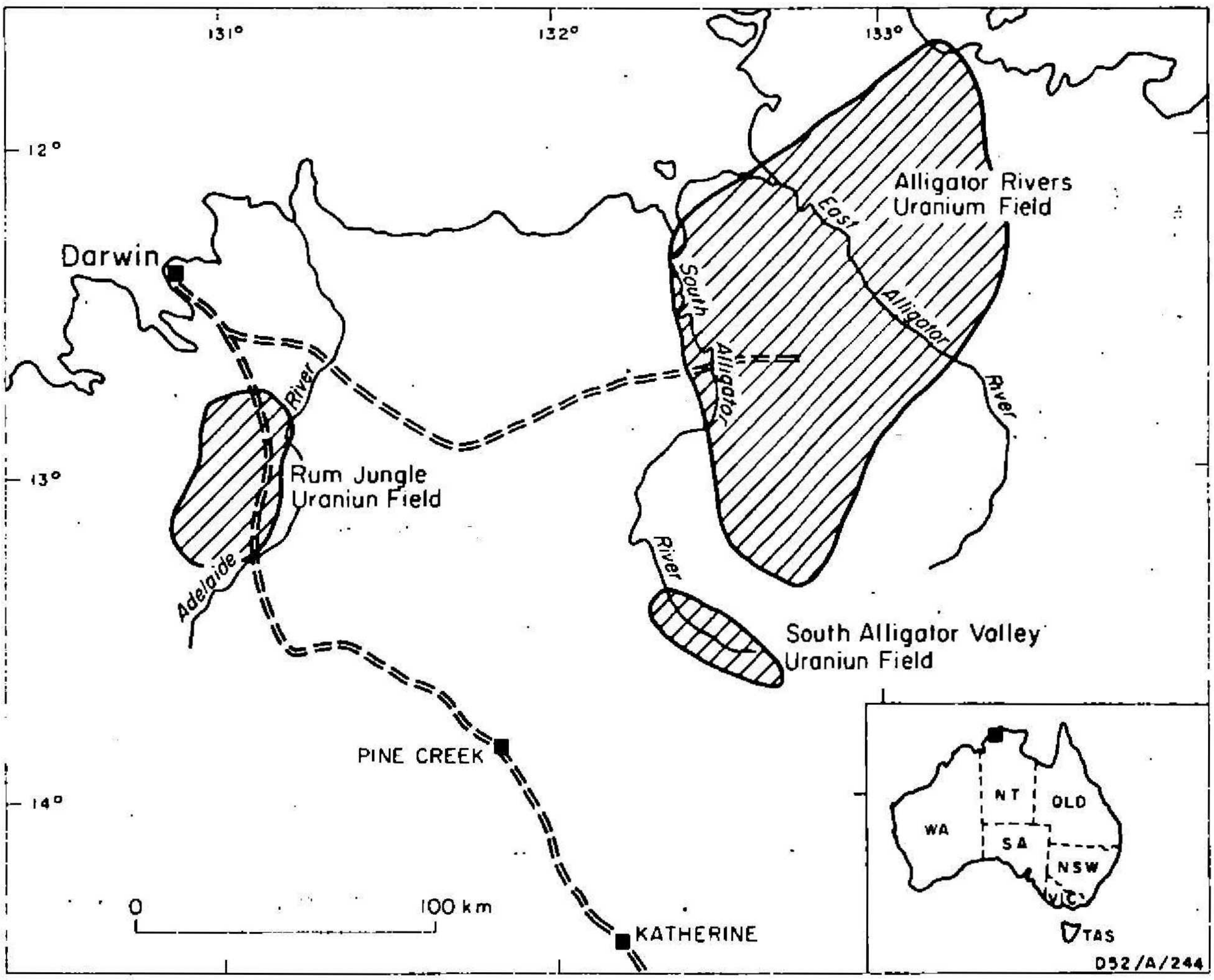


Fig. B20 The Alligator Rivers Uranium Field, N.T., in which major stratabound uranium deposits occur black shales and organic-rich carbonates (although no syngenetic deposits developed). Peneplanation of the terrain followed the ~1800-m.y. metamorphic event, and during this period a karst topography developed. Insoluble material collapsed into solution cavities; this material was mostly meta-psammitic and meta-pelitic material with clay (chlorite) and relatively fresh organic matter. These solution cavities were reducing zones in which carbonates formed with an organic carbon component, and bacterial sulphate reduction was occurring.

Low-temperature, oxidising, and mildly alkaline to neutral groundwaters percolated through the fracture systems scavenging uranium which was transported as the uranyl species, most probably as the carbonate complex. On encountering the different redox conditions in the anaerobic breccia zones, uraninite was precipitated. Specifically it is suggested that the uranium complex was sorbed onto chlorite, and was then reduced and sorbed as uraninite. Cyclic stripping has produced these large uranium orebodies.

At around 1700 m.y. the breccia zones were largely sealed by infill and alluvium, with the formation of the Kombolgie Formation. It is suggested that younger dates on these deposits represent reworking of the deposits.

EASTERN CREEK Pb-Ba PROSPECT, McARTHUR BASIN, NT

by

T.H. Donnelly

STAFF: T.H. Donnelly (in collaboration with M. Muir (BMR) and R.W.T. Wilkins (CSIRO))

The purpose of this study is to assess ore genesis through stable-isotope, mineralogical, fluid-inclusion, and detailed geological studies.

The Eastern Creek galena-barite prospect occurs in the Kookaburra Creek Formation. The mineralisation is conformable with bedding, and also occurs in cross-cutting bodies. On sedimentological grounds the environment of deposition is very shallow-water, possibly non-marine.

Field studies are nearing completion and some samples have been sectioned for petrological, S.E.M., and possible fluid-inclusion studies. Preliminary isotope studies indicate fairly constant $\delta^{34}S$ values for the barite (av. +18.8 $^{o}/oo$), whilst a chalcopyrite sample has a $\delta^{34}S$ value of +21.0 $^{o}/oo$ and a galena sample +11.2 $^{o}/oo$. Dolomite has fairly constant

$\delta^{13}C$ and $\delta^{18}O$ values (av. +1.1 & +21.8 $^{o}/oo$, respectively). The $\delta^{13}C$ values are in agreement with a normal sedimentary marine origin, whilst the $\delta^{18}O$ values (considering secular oxygen isotope trends) are either original values, or indicate recrystallisation from trapped seawater.

SIMILATED SEDIMENTARY STUDIES

by

B. Bubela

STAFF: J. Bauld, B. Bubela, James Ferguson, D. Fitzsimmons, I. Johns, L.A. Plumb, C.R. Robison, G.W. Skyring

The objectives for the simulated sedimentary system and the experimental results for the previous 12 months have been described in detail in the last Annual Summary. The following changes have occurred during the last 12 months period.

1. Porosity of the sediments:

The porosity of the sediments decreased gradually. The maximum decrease, of 30 percent, took place in the aragonite layer. This was due to the settling of the sediments, migration of small particles into interparticle spaces, and formation of iron sulphide by biological reduction of sulphate.

2. Permeability:

The permeability of the total sediments decreased from 330 mD to about 1 mD in the vertical direction. The horizontal permeability decreased from 640 mD to 460 mD. The major cause of the decrease in permeability was the organic component of the sediments. The permeabilities of the aragonite and magnesium calcite layers decreased from 1800 mD to 80 mD and 45 mD to 3.6 mD, respectively.

The different permeabilities of the individual layers and their variations in time are significant parameters influencing the flow and mixing of solutions in natural sediments.

The upper layers of the sediments became undersaturated due to biologically produced gases. This process may play a significant role during cementation of the sediments. On re-wetting at low hydrostatic pressures (inbibition), only some of the pores would become rehydrated. Cementation under these conditions, therefore, would be restricted to such pores only, and the porosity of sediments would be partially preserved.

The flow through the sediments is effected by capillary forces resulting from interfacial tension between the aquatic phase and the solid surfaces. On evaporation, the surface tension of the brine in the tank increased from 73 mN m^{-1} to 88 mN m^{-1}. The interstitial water isolated from the organic layer consistently gave an anomalous value of >100 mN m^{-1}. As the viscosity of the fluids increased from 1.056 cP up to 1.32 cP the movement of the fluids through the sediments was further hindered.

3. Algal mat:

The algal mat established itself to a thickness of about 5 mm on the water-sediment interface. Its permeability decreased to <0.1 mD, which caused evaporation through the surface of the sediments to be considerably hindered and water movement by capillary forces to be practically eliminated. This result has important implications with respect to movement of metals in sediments. The algal mat was stable up to 15 percent salinity in the supernatant water and did not decay even when surface water was evaporated and the algal mat was partly covered with evaporites.

During an investigation of conditions required for the establishing of the algal mat on the water-sediment surface, it was observed that if algal mat particles used as a seed were smaller than about 4 mm^2, the mat was difficult to establish. Particles of 1 cm^2 or larger became established and grew almost immediately.

To simulate the evaporative conditions of a saline marine environment the temperatures of the water and eventually of the surface of the sediments was raised to 35°C and the surface water was gradually evaporated.

Due to surface evaporation the content of dissolved solids in the overlying water has increased from 3.6 to 13 percent. Despite this increase, the concentration of the interstitial waters increased only marginally. This was due to the low permeability (√0.1 mD) of the algal mat formed on the water-sediment interface.

The algal mat eventually became covered by evaporites. It retained about 20 percent moisture despite the relatively high surface temperatures. This is probably due to the hygroscopic character of the halite formed on the algal mat. The algal mat became distorted, but the strongly reducing environment (about - 300 mV) was retained immediately below its surface. On rewetting, the mat became pliable, but its permeability remained low (about 1 mD). The effect of the algal mat on the evaporation of interstitial waters was measured. In the absence of the mat, water moved at the rate of about 10 cm/week: in areas covered by the mat, no water movement was observed in four weeks.

4. Evaporites:

Halite, gypsum, anhydrite, and small amounts of protodolomite were found in the crust of evaporites on top of the algal mat. Later the anhydrite and protodolomite were not detected and a strong peak of dolomite was found in the XRD pattern of the evaporites.

5. Organic matter:

To establish a pathway of diagenesis of organic material in sediments, organic matter was isolated from the similated system at several time intervals and compared with that isolated at the beginning of the experiment.

The total organic content of the sediments increased, with the exception of the lowermost strata, where it decreased from 700 ppm to 30 ppm. The maximum increase, 160 ppm to 16 000 ppm over the period of 10 months, was observed immediately under the surface of the algal mat. Such an increase can be explained by the photosynthetic processes operating at the sediment surface. The organic matter from samples collected during the last 15 months has been separated into humic, fulvic, and fatty acids, saturated and unsaturated hydrocarbons, and polar substances.

Approximately 110 samples are being analysed qualitatively and quantitatively by pyrolysis, gas chromatography, and mass spectrometry. It is hoped that the results will indicate some aspects of diagenetic pathways of organic matter in sediments.

6. Sulphate reduction:

Sulphate reduction rates in different layers of the simulation sediment have been assessed at intervals up to March, 1979. This phase represents the pre-evaporitic phase.

Within three months, sulfate reduction rates in the 0.5 cm layer had decreased to about 4 percent of the initial maximal rates (Table B4). In the layers below the surface, the most active sulphate reduction occurred in the iron layer adjacent to the organic layer. The next most active sulphate-reducing zone was the calcite layer.

7. Metals:

Several cores were collected from the system to study the movements of metals through carbonate, organic-matter-rich sediments under reducing environmental conditions.

As the evaporative cycle is completed, a fresh water/brine cycling period will be established shortly to study the diagenesis of metastable carbonates and their effects on metal accumulation, transport, and deposition.

ENHANCED OIL RECOVERY

by

B. Bubela

STAFF: B. Bubela, C.R. Manning

A grant of $112 000 from the National Energy Research, Development and Demonstration Council was received to investigate the feasibility of applying microbiological techniques to enhanced oil recovery. The following progress has been achieved so far:

a) An apparatus for a continuous growth of anaerobic microorganisms at pressures up to 20 000 kPa and temperatures (operative) up to 150 °C has been designed and constructed. At present it is undergoing safety tests.

b) A method has been developed to identify production of a surfactant by a single bacterial colony.

c) Several organisms capable of living under reservoir conditions have been isolated from oil well waters and artesian wells.

d) A number of pure microbiological cultures are being screened as potential surfactant producers.

TABLE B4. SULPHATE REDUCTION RATES IN TANK SEDIMENTS

Date	Porewater Sulphate mM	Sulphate Reduced mmol $m^{-2} d^{-1}$	Sulphide content	Sediment layer cm
29/9/78	121*	83*	12	0-5
31/10/78	88	64	12	0-5
11/1/79	157	25	14	0-5
7/2/79	140	8	7	0-5
9/3/79	93	0.5	23	0-5
21/7/78	101	1.3	4.0	8 aragonite
21/11/78	111	81	19	(iron
				15 (
21/11/78	111	6	38	(organic
21/11/78	99	18	10	27 calcite
31/10/78	109	1.5	5	8
31/11/78	100	0.1	39	15
31/11/78	92	29	8	27
31/11/78	43	1	1	41
7/2/79	130	2.0	7	8
7/2/79	55	0.1	44	15
7/2/79	9	0.01	10	27
7/2/79	43	0.3	2	41

* One determination

** Arithmetic mean of three estimates

METALLIFEROUS SECTION

Head: W.B. Dallwitz

GEOLOGICAL INVESTIGATIONS IN THE NORTHERN TERRITORY AND ANTARCTICA

Supervising Geologists:

D.H. Blake (Nov. 78-June 79), D.S. Trail (July-Aug.),

R.G. Dodson (Aug-Oct)

ARUNTA PROJECT

by

R.D. Shaw, A.J. Stewart, I.A. Offe, R.G. Warren, and A.Y. Glikson

STAFF: Full time - R.D. Shaw

Part time - I.A. Offe, A.J. Stewart, A.Y. Glikson, B.R. Senior, R.G. Warren, J.M. Mitchell; M.J. Freeman (Northern Territory Geological Survey), C. Mawser and J. Wilkie (Monash University), and D. Windrim (A.N.U.) 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 Basement in central Austrlia, so as to provide a basis for understanding the geological evolution of the region, and for the investigation of the region's mineral resources.

The main results of the year's work are:

1. The completion of a number of major Records, Reports, and Map Commentaries (see DATA PRESENTATION below);
2. Completion of field research in the Illogwa Creek 1:250 000 Sheet area:
3. Continued progress in map production of areas already mapped; four maps were printed, and another ten are in various stages of drafting (see below);
4. Preparation of a Microfiche Report giving stratigraphic definitions of rock units mapped in the Arunta region;
5. Publication of five papers in outside journals, dealing with magnetic interpretation of basement rocks, the first discovery of ruby in Australia, origins of sapphirine-bearing rocks, and evaporite rocks and algal fossils in the Amadeus Basin, south of the Arunta area. A sixth paper on kornerupine and sapphirine from the Harts Range is in press.

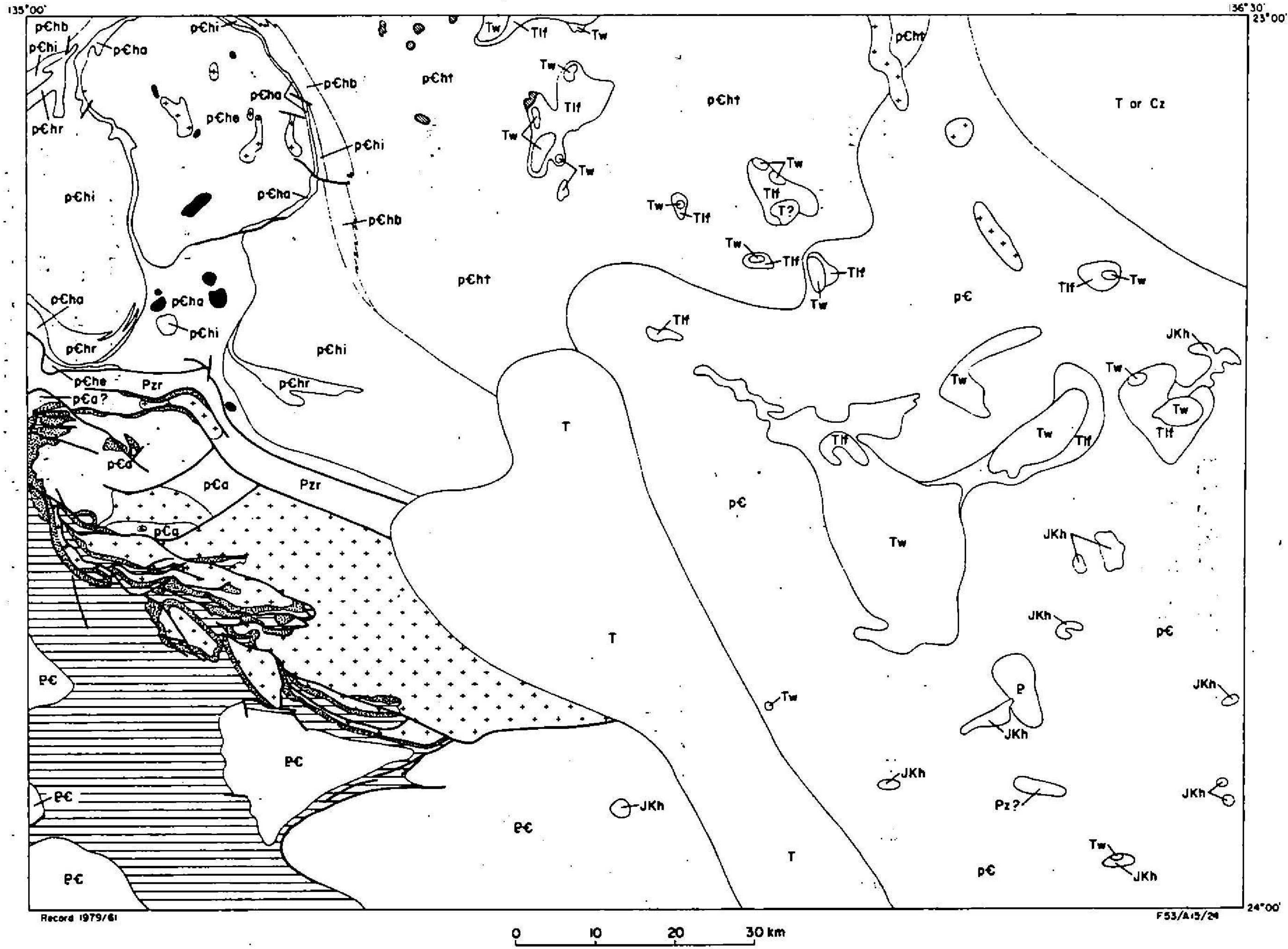


Fig. M1 Geological map of the Illogwa Creek 1:250 000 Sheet area

CAINOZOIC	Cz	*Thick sand and gravel outwash (sand cover)*
TERTIARY	Tw	*Chalcedonic limestone, some sandstone*
	T	*Shale, siltstone, some sandstone*
		Highly siliceous and ferruginised cap-rock
EARLY TERTIARY	Tn	*Ferricrete, deeply weathered rock*
JURASSIC TO CRETACEOUS	JKh	*Quartzose sandstone, capped by ferricrete*
PALAEOZOIC	Pzr	*Greenschist-retrograde schist zone*
PALAEOZOIC ?	Pz	*Sandstone*
UPPER PROTEROZOIC TO CAMBRIAN	p€	AREYONGA FORMATION to ARUMBERA SANDSTONE *(Composite section)* *Sandstone, siltstone, shale, calcarenite, diamictite*
UPPER PROTEROZOIC		BITTER SPRINGS FORMATION *Dolomite, limestone, shale, sandstone*
		HEAVITREE QUARTZITE *Sandstone, abundant granule and pebble conglomerate*
PROTEROZOIC	P	UNNAMED UNIT *Slightly metamorphosed arkosic sandstone and conglomerate*

Record 1979/61

LOWER ? PROTEROZOIC		*Granite, granodiorite, some tonalite; granitic gneiss*
		Metamorphosed and partly metamorphosed bodies of basic to ultrabasic composition
	p€o	ALBARTA METAMORPHICS* *Layered granitic gneiss, schist amphibolite, calc-silicate rock*
	p€	UNNAMED METAMORPHICS *Muscovite-biotite schist, biotite gneiss, metasandstone, quartzite*
	p€ht	ATULA METAMORPHICS* *Epidote-clinopyroxene calc-silicate rock, muscovite-biotite gneiss, biotite gneiss*
	p€hb	BRADY GNEISS *Garnet-bearing muscovite-biotite schistose gneiss, biotite gneiss, small amounts of para-amphibolite and calc-silicate rock*
	p€hi	IRINDINA GNEISS *Garnet-quartz-plagioclase schistose gneiss, layered amphibolite calcareous rocks*
	p€hr	RIDDOCK AMPHIBOLITE MEMBER *Layered amphibolite, biotite schistose gneiss, garnet-bearing quartzofeldspathic gneiss*
	p€ha	BRUNA GNEISS *Gneiss containing conspicuous K-feldspar megacrysts*
	p€he	ENTIA GNEISS *Quartzofeldspathic gneiss, layered amphibolite, hornblende gneiss, some calcareous rocks*

* *Informal name*

F53/A15/25

Fig. M2 Reference for Fig. M1

DATA PRESENTATION (R.D. Shaw, A.J. Stewart, I.A. Offe, R.G. Warren)
ALICE SPRINGS 1:250 000 SHEET AREA.

The drawing of the Preliminary 2nd Edition of Alice Springs 1:250 000 map is complete. However, there are still major editorial problems due to poor topographic information, mismatch between topographic detail and geology, and excessive geological detail in some parts. A first draft of the Explanatory Notes has been prepared.

The 1:100 000 special map of the STRANGWAYS RANGE REGION, incorporating LAUGHLEN and part of BURT, 1:100 000 sheets is with the map editors. The Map Commentary is with the editors, who recommended shortening the text.

The 1:100 000 special map of the ALICE SPRINGS REGION is almost complete; the map includes the main tourist areas close to Alice Springs, and incorporates basement rocks in ALICE SPRINGS and UNDOOLYA, and in a small part of MACDONNELL RANGES. Writing of the Map Commentary is well advanced.

The Preliminary Edition of the FERGUSSON RANGE is now available. Drafting of the face of RIDDOCH is two-thirds complete. There are no plans, at present, to produce 1st Edition maps and Commentaries of these two Sheet areas.

A large and detailed microfiche Record on all the above 1:100 000 mapping areas has been approved and typed ready for microfiche. A separate Record details information on known mineral deposits in the whole Alice Springs 1:250 000 Sheet area. A manuscript was completed on the rare assemblage garnet-sapphirine-orthopyroxene-spinel from Oonagalabi in the Harts Range, and passed to the supervisor for edit.

HERMANNSBURG 1:250 000 SHEET AREA
MacDonnell Ranges 1:100 000 Sheet area

Preparation of compilation sheets of this area revealed a number of serious gaps in the field observations. Consequently about three weeks was spent on field checks during the 1979 season.

Anburla and Narwietooma 1:100 000 Sheet areas

Final compilation of these sheets was held over while field checks were completed during the 1979 season. A suite of samples, mainly of mafic granulite, has been sent for geochemical analysis.

NAPPERBY 1:250 000 SHEET AREA

A special 1:100 000 map of the REYNOLDS RANGE REGION has been prepared, combining REYNOLDS RANGE and parts of AILERON, TEA TREE, and MOUNT PEAKE. Preliminary 1:100 000 maps are already available of all these areas. DENISON is undergoing supervising draftsman's edit. A draft Map Commentary on the Reynolds Range Region has been written.

A detailed Record of both 1:250 000 and 1:100 000 scale mapping in the northwestern Arunta region is complete, except for the summary. Drafting of a new edition of the Napperby 1:250 000 Sheet, which incorporates the results of all 1:100 000 scale mapping in the area, is about 40 percent complete.

ALCOOTA 1:250 000 SHEET AREA

Record 1975/100 was updated, and was being printed at the end of the year.

SOUTHWEST GEORGINA BASIN

A contribution to 1:250 000 mapping of basement rocks in the Hay River and Tobermory 1:250 000 Sheet areas has been completed, together with a contribution to a regional summary paper.

HUCKITTA 1:250 000 SHEET AREA

A pre-survey Record and photo-interpretation of the Arunta Basement have been completed in preparation for field work, possibly in 1980. Available data (company reports and previous work by BMR) were used as a basis for the photo-interpretation. The results suggest that overthrust fault blocks may be present next to the Tarlton Fault and at the western edge of the Jervois Range. Overthrusting west of the Tarlton Fault would account for the distribution of basement and cover rocks near Mount Cornish. Overthrusting may also have moved the Jinka Granite over the Proterozoic and Early Cambrian units of the Georgina Basin to the north.

FIELD ACTIVITIES

ILLOGWA CREEK 1:250 000 SHEET AREA (R.D. Shaw, I.A. Offe, B.R. Senior, J.M. Mitchell)

The Illogwa Creek 1:250 000 Sheet area was mapped in cooperation with the Northern Territory Geological Survey (M.J. Freeman). A simplified interpretation of the geology is shown in Figures M1 and M2. Special points of interest arising from the mapping are:

1. A unit of calc-silicate rock and schist, informally known as the Atula metamorphics and covering a large part of the Sheet area to the east, has been shown to interfinger with and overlie the Bredy Gneiss - previously the youngest recognised unit of the Harts Range Group. Scheelite occurs in similar calc-silicate rock associated with granite in the Bonya-Jervois area to the north, in the Huckitta 1:250 000 Sheet area.
2. The recently discovered ruby-corundum deposit at the Spriggs Camp Prospect was shown to be confined to rare pods of hornblende (containing 1.5 percent Cr_2O_3)-anorthite gneiss accompanied by a chlorite-phlogopite-hornblende para-amphibolite. These pods are localised in a distinctive hornblende-bytownite gneiss unit of the Riddock Amphibolite Member of the Irindina Gneiss. This gneiss unit can be traced over a strike length of at least 15 km, and is thought to be a metamorphosed calcareous sediment which contained lenses of gibbsitic marl.
3. A number of highly ferruginous and silicified cappings in the northern-central part of the Sheet area are thought to have formed on small, non-outcropping ultrabasic bodies.

4. Near the central-eastern edge of the Sheet area, an unusual sequence of rocks, informally referred to as the Albarta metamorphics, consists of well-layered granitic gneiss (thought to be meta-arkose or meta-volcanics), calc-silicate rock, amphibolite, and schist. These metamorphics contain a number of areas with above average scintillometer counts.
5. A major thrust-fault has been delineated north of the Illogwa Schist Zone.
6. Numerous small granite bodies have been discovered on the northeastern flank of the Harts Range. About 70 km farther east small granite bodies occur in domal structures similar to those surrounding the Huckitta and Inkamulla Granodiorites in the Harts Range.
7. The Albarta metamorphics in the southwestern part of the Sheet area are intruded by an extensive igneous complex of granite to tonalite composition. The complex is overlain by the Heavitree Quartzite, and the whole area has undergone extensive high-angle reverse faulting during the Alice Springs Orogeny in Devonian-Carboniferous time. This is similar to the geological setting of the Arltunga Gold Field, 50 km to the west.
8. In the southwest of the Sheet area, the lower part (Gillen Member) of the Bitter Springs Formation has been divided into five units to help resolve its structure. Several gypsum occurrences were located in the Formation. One of these, which is considered to be a bedded evaporite, is in the middle of the Gillen Member.

HERMANSBURG 1:250 000 SHEET AREA (A.Y. Glikson, I.A. Offe, R.D. Shaw)

GLEN HELEN was mapped, and field checks were carried out in MACDONNELL RANGES and HERMANNSBURG. GLEN HELEN includes the best outcrops documented to date of the Redbank fault zone, previously delineated in HERMANNSBURG and MACDONNELL RANGES. The following principal units were documented within GLEN HELEN:

(1) <u>Felsic granulites at Mount Zeil</u>: Felsic to intermediate granulite facies gneisses dominate the terrain north of the Redbank fault zone, and include small bodies of mafic granulite, particularly in the vicinity of the fault. Near the

fault the granulite forms resistant ridge-forming thrust sheets which dip 20-30° north. The most spectacular is the Mount Zeil escarpment, which consists of felsic granulite thrust over migmatite; the two units are separated by a mylonite-cataclastic gneiss zone several hundred metres thick.

(2) Intermediate to mafic granulites at Mount Chappell: This suite, which also includes zones of felsic granulite, occurs north of the Redbank fault zone and the granulites at Mount Zeil, particularly west of the Dashwood River.

(3) Metasediments of the Chewings Range-Haast Bluff area: A series consisting of amphibolite-facies quartzofeldspathic paragneiss, calc-silicate rock, para-amphibolite, minor pelitic metasediments, quartzite, and epidote quartzite was mapped west and north of Glen Helen, and is particularly well developed west of the Derwent River between the Haast Bluff Range and Redbank fault zone, where calc-silicates predominate.

(4) Migmatites at Glen Helen: This unit includes classic migmatites and banded gneisses, both including palaeosome segments of biotite gneiss detached by quartzofeldspathic neosome mobilisate. All degrees of anatexis and assimilation of a pre-existing biotite-plagioclase-K-feldspar-quartz gneiss complex - traceable into the Chewings Range metasedimentary succession - are represented.

(5) Teapot porphyritic granite: Medium to coarse-grained granite, displaying a well developed flow structure of oriented K-feldspar phenocrysts, forms the bulk of the terrain between the Redbank zone and the Mount Sonder-Mount Razorback thrust in the area to the north of these two mountains. This pluton forms the core of the Glen Helen migmatites.

(6) Basic stocks and dykes associated with the Redbank fault zone: Some of these consist of basic granulite, and some of post-metamorphic gabbro, such as three syenite-mantled gabbro stocks southwest of the Mount Zeil thrust. Some of the basic bodies cut through the mylonite.

The Redbank fault zone includes two principal components (phases).

(a) Older Redbank blastomylonite-gneiss and blastomylonite of Redbank Hill, within the northern granulite facies terrain.

(b) Younger mylonite, blastomylonite, and phyllonite zone of the Mount Heughlin-Mount Zeil-Redbank Ruins thrust, which separates the northern granulite facies terrain (units 1 and 2) from the southern amphibolite facies migmatite-gneiss terrain (units 3, 4, 5).

Phyllonite occurs along zone (b), but not along zone (a), reflecting movements of post-regional metamorphism age, probably in part coincident with the Carboniferous Alice Springs Orogeny. Occurrence of Heavitree Quartzite (ca. 900 m.y.) north and south of zone (b) west of the Derwent River suggests little if any movement in this area in late Proterozoic or Phanerozoic times. Isotopic dating of mylonites and rock units associated with the Redbank zone is required. The Redbank fault zone and associated basic intrusions suggest a tectonic environment favourable for occurrence of kimberlites. The occurrence of a garnetiferous mafic granulite-anorthosite complex (Mount Hay) north of zone (b) signifies an upthrusted subcrustal layer, as corroborated by associated intense bouguer and aeromagnetic anomalies.

MISCELLANEOUS ACTIVITIES

R.D. Shaw gave a lecture at the BMR Symposium on 'The evolution of Arunta basement rocks in the Alice Springs region, and their relation to mineralisation'. A.J. Stewart gave a BMR Tuesday-morning lecture on the 'Tectonic Setting of the Arunta Block'.

DARWIN OFFICE

by

C.E. Prichard

STAFF: C.E. Prichard, P.H. Fuchs (to February 1979), P.R. Lachlan (to January 1979), N.A. Ashmore, A.J. Neilsen

The drawing office was closed at the end of 1978, and the drafting officer and drafting assistant transferred to positions in the Northern Territory Public Service. They had completed drafting the OENPELLI and HOWSHIP 1:100 000 Preliminary Editions, had made alterations to JIM JIM Preliminary Edition, and had compiled all available overlays for TIPPERARY. All work in progress and drafting equipment has been transferred to Canberra.

The base, store, and workshop at Tannadice Street remained unstaffed throughout the year. Twenty-three vehicles and field equipment were stored there by field parties at the end of the 1978 field season. The Pine Creek Party mechanic spent a month servicing these vehicles.

At the beginning of the 1979 field season, parties collected their vehicles and stores. The Pine Creek Geological Party, the Alligator Rivers Hydrogeological Party, the Gemco Drilling Party, and a geophysical party were all operating in the area during 1979, and received support and assistance as required. In addition the USSR Gravity team and the Marine Geophysics team joining the Cape Pillar cruises received assistance. The shore magnetic station for the latter survey was operated by Darwin Office staff.

The Darwin Office was directly involved in the planning and running of the pre- and post-symposium tours for the International Uranium Symposium on the Pine Creek Geosyncline, and in preparation of the Excursion Guide. 240 delegates attended the excursions. C.E. Prichard attended the Symposium in Sydney, chaired one session, and acted as a referee for three of the papers to appear in the Proceedings.

In February 1979 a new permit system for entry onto Aboriginal land in the Northern Territory commenced. The group liaised with the authorities, and arranged nearly 100 permits for BMR officers required to work in the Northern Territory.

Services to the general public, schools, and the mining industry were in steady demand throughout the year. Map and publication sales averaged about ninety/month. School teachers and students are increasingly enquiring about geological maps, excursions, and projects. A group from the Science Teachers Association of the Northern Territory visited the office, and were shown the seismic recorder and publications available.

Manton Seismic Station was adjusted and serviced in August, and is now operating satisfactorily on all three components. First arrivals are notified twice weekly.

PINE CREEK GEOSYNCLINE PROJECT

by

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

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

INTRODUCTION, by R.S. Needham

The objectives of this project are:

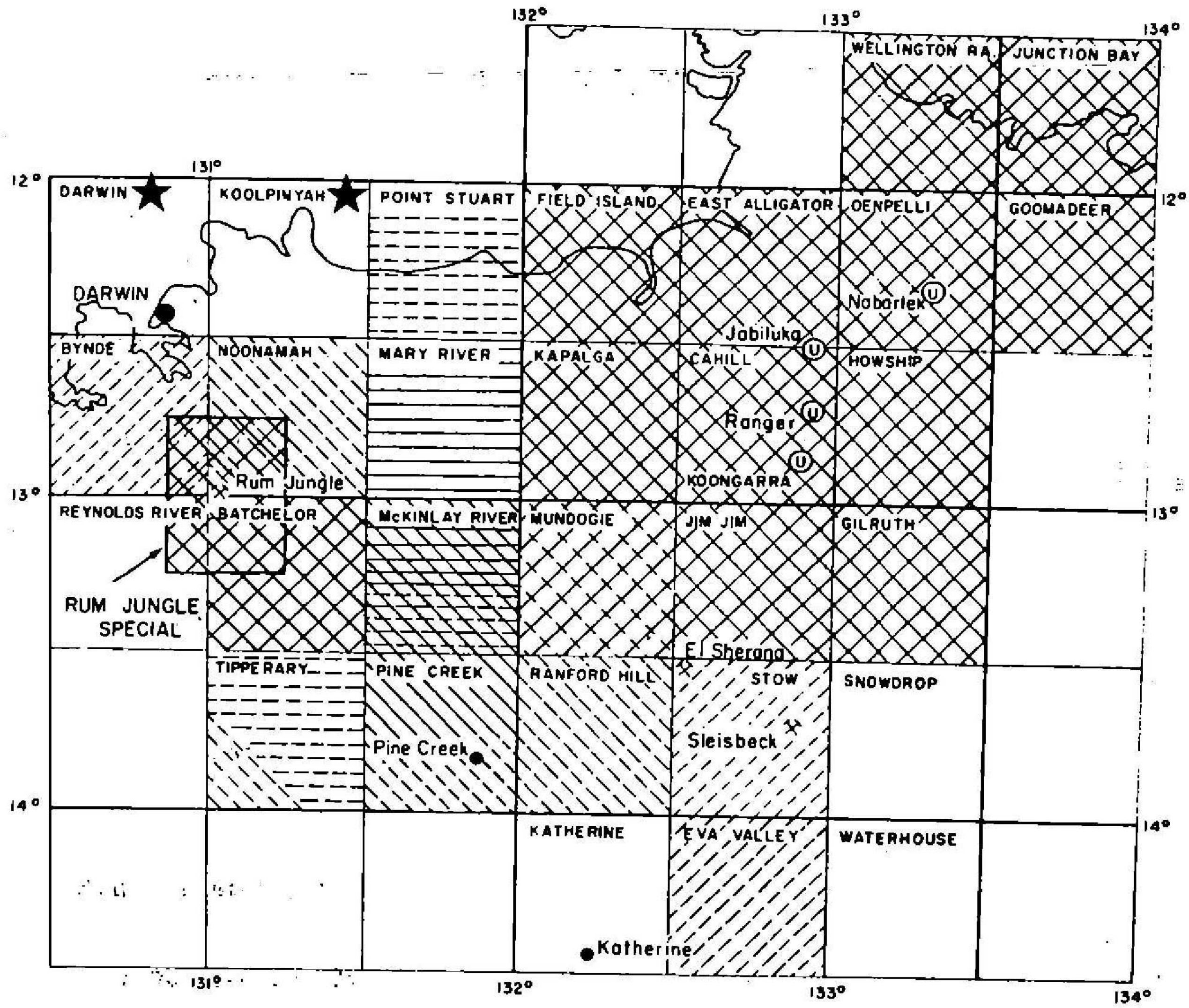
1. To gain a more detailed understanding of the geology of the Pine Creek Geosyncline.
2. To indicate the controls and distribution of uranium and other mineralisation in the geosyncline.
3. To prepare and publish a new series of 1:100 000-scale geological maps, and to revise the 1:250 000-scale geological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

The Pine Creek Geological Party is part of a multidisciplinary team studying many aspects of the geosyncline. Geophysical work is being done by A. Mutton, geochemical work by P. Scott, C. Madden, B. Cruikshank, J. Pyke, J. Ferguson, and G. Ewers, geochronology by R. Page, and palaeomagnetics by M. Idnurm and J. Giddings. The results of research by other groups are presented elsewhere in this Record, and in the annual summaries of other branches of BMR.

To date seventeen 1:100 000 Sheet areas have been covered by semi-detailed field work; twelve Preliminary standard series 1:100 000 maps and one Preliminary special 1:100 000 map have been published, and five more standard series Preliminary maps are at an advanced stage. Field compilation sheets, mainly at 1:25 000 or 1:50 000 scale, are available for all areas investigated to date. During 1979 emphasis has been on petrological studies of rocks from the Mary River Sheet area, on field work in the McKinlay River and Pine Creek Sheet areas, on establishing correlations with the Rum Jungle and Burnside areas and revision of stratigraphy where necessary, and on preparation of maps and papers for the International Uranium Symposium on the Pine Creek Geosyncline which was held in June. Members of the party contributed to seven papers, prepared two special maps of the geosyncline at 1:500 000 and 1:2 000 000-scale, helped to prepare the excursion guide, refereed papers, and acted as excursion leaders. A reconnaissance was made of parts of the Litchfield Block, and suites of granitic rocks were collected for age determination by R.W. Page. Page also collected suites of lower Proterozoic to Carpentarian acid and basic intrusive rocks, and volcanic rocks for age determination throughout the geosyncline (see Geochronology Laboratory report, this Record). With current manpower the geological investigations will be completed in about 6 years.

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

Progress of map production is shown in the frontispiece and in Fig. M3. JIM JIM, HOWSHIP, and OENPELLI 1:100 000 Preliminary maps were issued during the year. Checking of the final draft of the MUNDOGIE Preliminary is in progress. CAHILL and EAST ALLIGATOR have been edited and amended for First Edition and are ready to be fair-drawn; map commentaries have been prepared for both sheets and are being edited. The Second Edition Alligator River 1:250 000 map is being drawn, and Explanatory Notes are being prepared. A Bulletin describing the geology of the Alligator Rivers Uranium Field is being prepared. A data Record containing compilation sheets and thin-section descriptions from the Mundogie Sheet area was issued, and a Record describing results of studies in the Alligator Rivers area from 1973 to 1976 is with the printing section. Records describing the geology of the Mundogie Sheet area, and results of drilling in the Munmarlary area in 1978, are in an advanced stage of preparation. The papers prepared for the International Uranium Symposium described the regional geology of the Pine Creek Geosyncline, the geology of the Alligator Rivers Uranium Field, the geology and mineralisation of the South Alligator Uranium Field, a regional survey of metallic mineralisation in the Pine Creek Geosyncline, the evolution of the Pine Creek Geosyncline, evaporites and uranium mineralisation in the Pine Creek Geosyncline, and geochronology and evolution of the late Archaean basement and Proterozoic rocks in the Alligator Rivers Uranium Field. Needham was the main author of the excursion guide prepared for the Symposium, and prepared a review paper of the June symposium for the AIMM annual conference held in August. Needham also contributed to a paper on the Proterozoic of Northern Australia for the Hunter volume on the geology of the Southern Continents, and wrote a professional opinion on the mineral development potential of the Goodparla and Gimbat pastoral leases. Crick was a joint author of a paper describing stable isotope and chemical studies of volcanic exhalations and thermal waters from Rabaul Caldera, published in the BMR Journal. Special colour maps of the Pine Creek Geosyncline at 1:500 000 and 1:2 000 000 scale were issued in connexion with the June Symposium.



MAPPING COMPLETED 1971-1979

- 1:100 000 preliminary edition issued
- 1:100 000 preliminary edition in progress
- Field compilation completed
- Field compilation in progress

MAPPING IN PROGRESS OR ON PROGRAM

- Mapped, 1979
- On program, 1980
- On program, 1981, 1982
- ★ Mapped by N.T Geological Survey, 1979

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Fig. M3 Progress of geological mapping and index to 1:100 000 Sheet areas, Pine Creek Geosyncline Project

MARY RIVER AND POINT STUART 1:100 000 SHEET AREAS, by P.G. Stuart-Smith

A Record presenting preliminary data from the 1978 fieldwork in the Mary River and Point Stuart Sheet areas is currently being prepared. Petrographic work on drill core from the 1978 drilling program has confirmed the volcanic origin of the extremely weathered ferruginous fine massive rocks previously mapped as dolerite sills intruding the Wildman Siltstone northeast of the Mount Bundey Granite. The rocks are chloritised and carbonated amygdaloidal andesite and tuffaceous pyritic carbonaceous shale. The volcanics, about 100 m thick, are interbedded with the Wildman Siltstone at two horizons, 250 m and 500 m above its base. They are informally referred to as the 'Annaburroo Volcanic Member' and are probably equivalents of the 'Mount Deane Volcanic Member' in the Rum Jungle area, which has been variously interpreted by earlier workers as dolerite and ironstone.

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

Field work in MCKINLAY RIVER was completed during 1979, together with 20 percent of PINE CREEK.

The area of research covers part of the eastern limb and base of a synclinorium which extends westwards to Rum Jungle. Alluvium of the McKinlay River floodplain covers much of the northern and central parts of the area, and Cainozoic lateritic sands and minor Cretaceous sandstone overlie most of the lower Proterozoic strata east of the Mary River. Elsewhere exposure is excellent.

The lower Proterozoic metasediments are tightly to isoclinally folded, north-trending, and young towards the west. The oldest rocks, metasediments of the Masson Formation, are exposed along the eastern boundary of the McKinlay Sheet. The sediments are intruded by Zamu Dolerite dykes and sills and by three Carpentarian granites - the Cullen, Margaret, and Prices Springs Granites. In the western half of the Sheet area doming associated with the Margaret and Prices Springs Granites exposes inliers of South Alligator Group rocks surrounded by the Burrell Creek Formation (Fig. M4).

The major significant revision of previous work is a re-interpretation of rocks previously regarded as Masson Formation along the western margin of the Cullen Granite as members of the younger Wildman Siltstone.

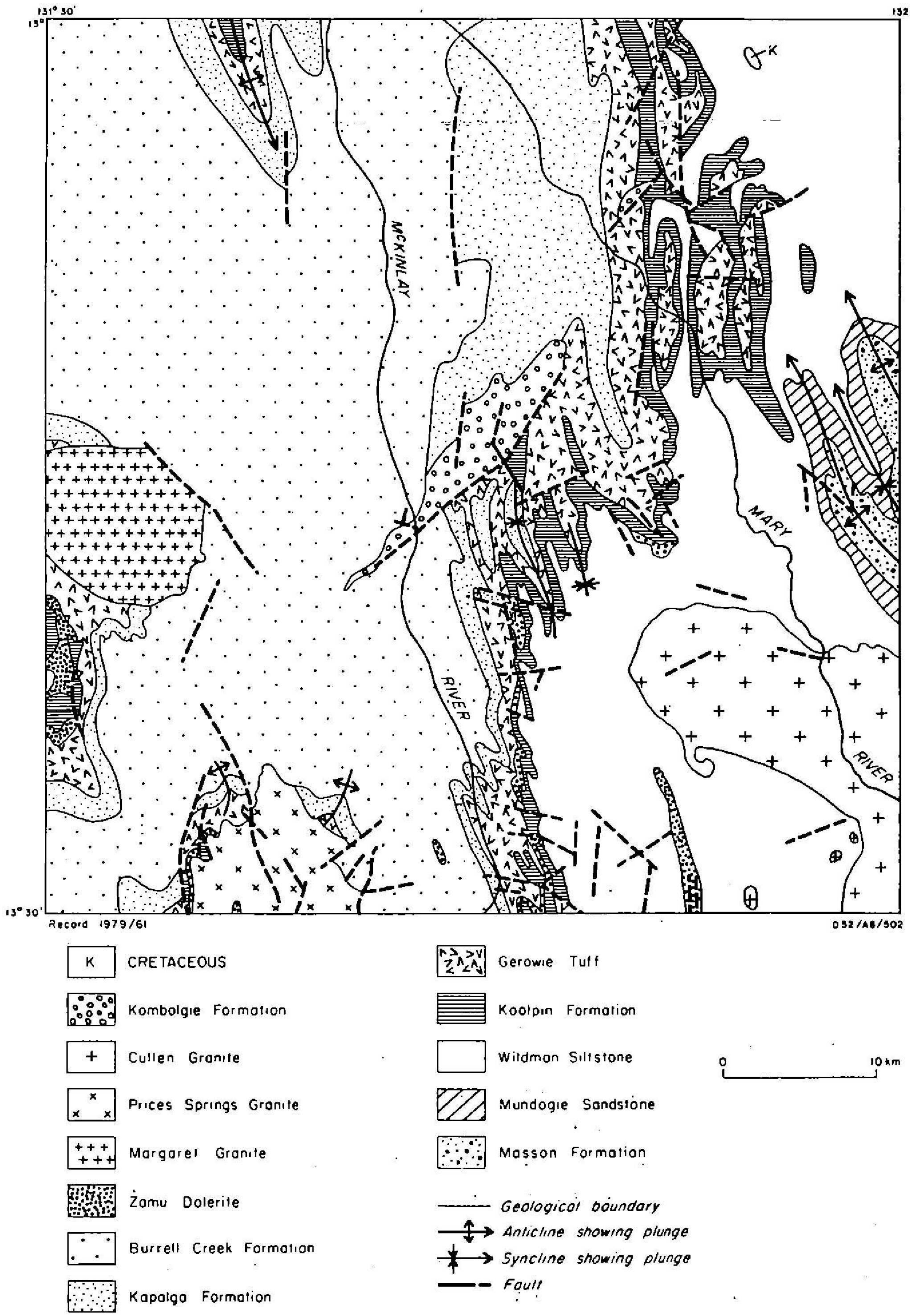


Fig. M4 Solid geology, McKinlay 1:100000 Sheet area, Pine Creek Geosyncline

The Masson Formation crops out as two northwesterly-trending lobes of ferruginous shale, sandstone, and minor quartzite east of the Mary River. These are unconformably overlain by quartz-rich psammites and conglomerates of the Mundogie Sandstone. This unit is a correlative of the Mount Hooper Sandstone, which crops out further north mainly as domes within the Wildman Siltstone.

West of the Cullen Granite the Wildman Siltstone has been sub-divided into five members, provisionally numbered Ppw_{1-5}, with a total thickness of 2000 m:

Ppw_5 (400 m) - siltstone, thinly interbedded fine quartzite, limonitic sandstone, shales and minor coarse quartzite (topmost unit).

Ppw_4 (600 m) - siltstone, sandy siltstone, shale and very minor quartzite. Pelitic rocks are colour-banded in places. Includes two ironstone horizons, the lower of which has been exploited commercially at Frances Creek.

Ppw_3 (300 m) - coarse arkose, pebbly in places, quartz arenite, minor quartzite and shale.

Ppw_2 (150 m) - laminated to thinly bedded colour-banded shale, siltstone, sandy siltstone and minor fine quartzite.

Ppw_1 (500 m) - medium-grained grey quartzite, minor siltstone, and shale (lowermost unit).

Within contact-metamorphic aureoles the carbonaceous colour-banded pelites are distinctively graphitic and usually accompanied by the prominent development of andalusite and mica.

Unconformably overlying the Wildman Siltstone is a narrow but continuous unit of highly ferruginised chert-nodular shale, siltstone, and localised limonitic sandstone, the Koolpin Formation. This unit is 100-200 m thick, and generally thins out southwards in common with the other members of the South Alligator Group in the area. Banded ironstone occurs patchily. Massive silicified dolomite is commonly present at the base, together with very rare fresh dolomitic carbonate.

The ferruginous sediments of the Koolpin Formation are abruptly transitional into a 350-m-thick sequence of black crystal tuff, shale, and quartz argillite of the Gerowie Tuff. This boundary is typically several metres wide and consists of interbedded slightly ferruginous sediments of both units. The Gerowie Tuff is distinguished by its bleached rubbly outcrop, sparse vegetation, and high topographic relief.

The uppermost unit in the South Alligator Group, the Kapalga Formation, is conformably transitional over the Gerowie Tuff. The Kapalga Formation is characterised by a progressive decrease in crystal tuff up the sequence, and the presence of greywacke (feldspathic litharenite) interbedded with slate, black chert nodules, laminated black and green chert, and minor argillite. The Kapalga Formation is distinguished from the Gerowie Tuff by a darker, reddish photo tone, lower relief, and poorer exposure.

The Burrell Creek Formation, the youngest and most extensive lower Proterozoic unit in the area, crops out over most of the western half of the region studied. It is conformable on the Kapalga Formation and consists of interbedded slate, phyllite, siltstone, feldspathic litharenite, and lenses of 'tombstone' greywacke. Fine to medium-grained rocks, constituting about 80 percent of the unit, are strongly cleaved, and weathered to a russet colour. The rocks are cut by numerous quartz reefs. Despite its thickness, estimated at more than 2 km, the lack of continuous marker horizons precludes further subdivision.

Dolerite sills and dykes intrude the lower Proterozoic strata throughout the area. The intrusives are most common within South Alligator Group sediments, especially in the Koolpin Formation. The dolerite is usually dark green due to extensive chloritisation of feldspar. A rare dioritic differentiate intrudes Burrell Creek Formation siltstone near the centre of the area.

Sampling of the three granite bodies substantiated the presence of the five granite phases identified by earlier work. Hornfelsed aureoles in lower Proterozoic country rocks extend up to 1 km from the outcrops of the granite margins.

<u>RUM JUNGLE SPECIAL SHEET AREA</u>, by I.H. Crick

Parts of this Sheet area not covered by last year's field work (which concentrated on the southeast quarter, i.e. northwest part of BATCHELOR) were examined in order to establish more clearly the Lower Proterozoic stratigraphy.

The quartzites and interbedded siltstones of the Acacia Gap Sandstone form a well-defined unit distinguishable in other parts of the Pine Creek Geosyncline as part of the Wildman Siltstone.

Within the Embayment area, the Acacia Gap Sandstone is exposed in Dyson's Open Cut, formerly considered to be in the Masson Formation. Carbonate units in the open cut are not typical Coomalie Dolomite as previously thought, but contain coarse-grained ?calcite, probably derived from late-stage solution of the Coomalie Dolomite. Carbonate units of the Coomalie Dolomite from the nearby White's and Intermediate's Open Cuts are dolarenites, commonly brecciated but unmineralised, and coarse-grained ?magnesite containing gypsum pseudomorphs. Calcite veining is common and, in one example, the veins contain sulphides and radioactive minerals. It is possible, therefore, that late-stage partial solution of these carbonates, resulting in formation of calcite veins, was important in remobilising uranium in the Embayment area and may have caused uranium mineralisation at Dyson's Open Cut.

The Koolpin Formation north of the Rum Jungle Complex is demonstrably unconformable over siltstones of the Wildman Siltstone. One exposure contains rare quartzite boulders from the Acacia Gap Sandstone, in a hematite-limonite matrix interpreted as a fossil regolith. Nearby, rare greenish-grey highly altered ?tremolitic rock within the Wildman Siltstone above the Acacia Gap Sandstone displays ellipsoidal to spherical layered structures reminiscent of weathering features in volcanics, and xenoliths of chert nodules and siltstone at its base. Possible flow-breccias and amygdales occur in a similar rock type at Mount Deane. This rock type is probably an altered basic lava and is informally referred to as the Mount Dean Volcanic Member.

TIPPERARY SHEET AREA, by I.H. Crick

No further work was done on this Sheet area. Field work is about 80 percent complete and completion is at the discretion of the N.T. Geological Survey which is jointly participating in this work.

STRATIGRAPHIC DRILLING, by R.S. Needham

An angled diamond core hole was drilled by N.T. Mines Department into Gerowie Tuff and Koolpin Formation 1 km west of the Mary River bridge in the Mount Bundey area. The hole intersected mainly tuff and argillite of the Gerowie Tuff and over 20 m of carbonaceous shale of the Koolpin Formation. The hole was abandoned at 376.8 m owing to difficult drilling conditions. The core has been logged and samples selected for thin sectioning and analysis.

Ten auger drill holes were put down over a 35-km traverse along the Point Stuart road, commencing at the turnoff on the Arnhem Highway. Grey and black banded carbonaceous shale was intersected in most holes, but the two most northerly were in silicified quartzite. All holes appear to have been in the Wildman Siltstone. Depth of weathering in some holes was over 100 m.

LITCHFIELD BLOCK RECONNAISSANCE, by R.S. Needham & P.G. Stuart-Smith

A three-day reconnaissance of the Litchfield Block was made on 1-3 August by R.S. Needham, P.G. Stuart-Smith, and R.W. Page, to examine access, terrain, and the character of rock exposures, and to collect a suite of samples for petrographic and geochronological studies if suitable.

The rocks of the Litchfield Complex are massive to foliated garnetiferous granodiorite which overall are most leucocratic in the north. In the southern outcrop area southwest of Daly River township the granodiorite commonly contains elongate, mafic to siliceous, massive to banded xenoliths, and in places is cut by aplite veins. At one locality (location 1, fig. M5), banded to nebulitic migmatite textures are well developed, and the rock contains bands of kyanite gneiss and banded xenoliths. Rare outcrops of quartz-rich granodiorite between location 1 and Daly River township were seen on extensive wooded sandy plains, and red soil appeared to indicate subsurface mafic rocks. A well-foliated quartzite was exposed in a creek crossing in this area. At locality 2 (fig. M5), the granodiorite intrudes massive to foliated cordierite hornfels, possibly of the Hermit Creek Metamorphics. The granodiorite is altered near the contact, and contains scattered secondary copper mineralisation (see below). The hornfels is unconformably overlain by unmetamorphosed and slightly deformed Chilling Sandstone and Berinka Volcanics.

The Mount Litchfield area (location 3, Fig. M5), is a hilly terrain with widespread fresh exposure of granodiorite within extensive sand plains. These rocks are less mafic than those southwest of Daly River township, and range from massive to weakly foliated to porphyroblastic types, to types containing streaky clots of biotite. In places they are cut by numerous pegmatite dykes up to 2 m wide.

The northern area of Litchfield Complex rocks is north of Welltree Station (location 4, Fig. M5). The rocks of this area are the most leucocratic of those seen during the reconnaissance of Litchfield Complex rocks, and in

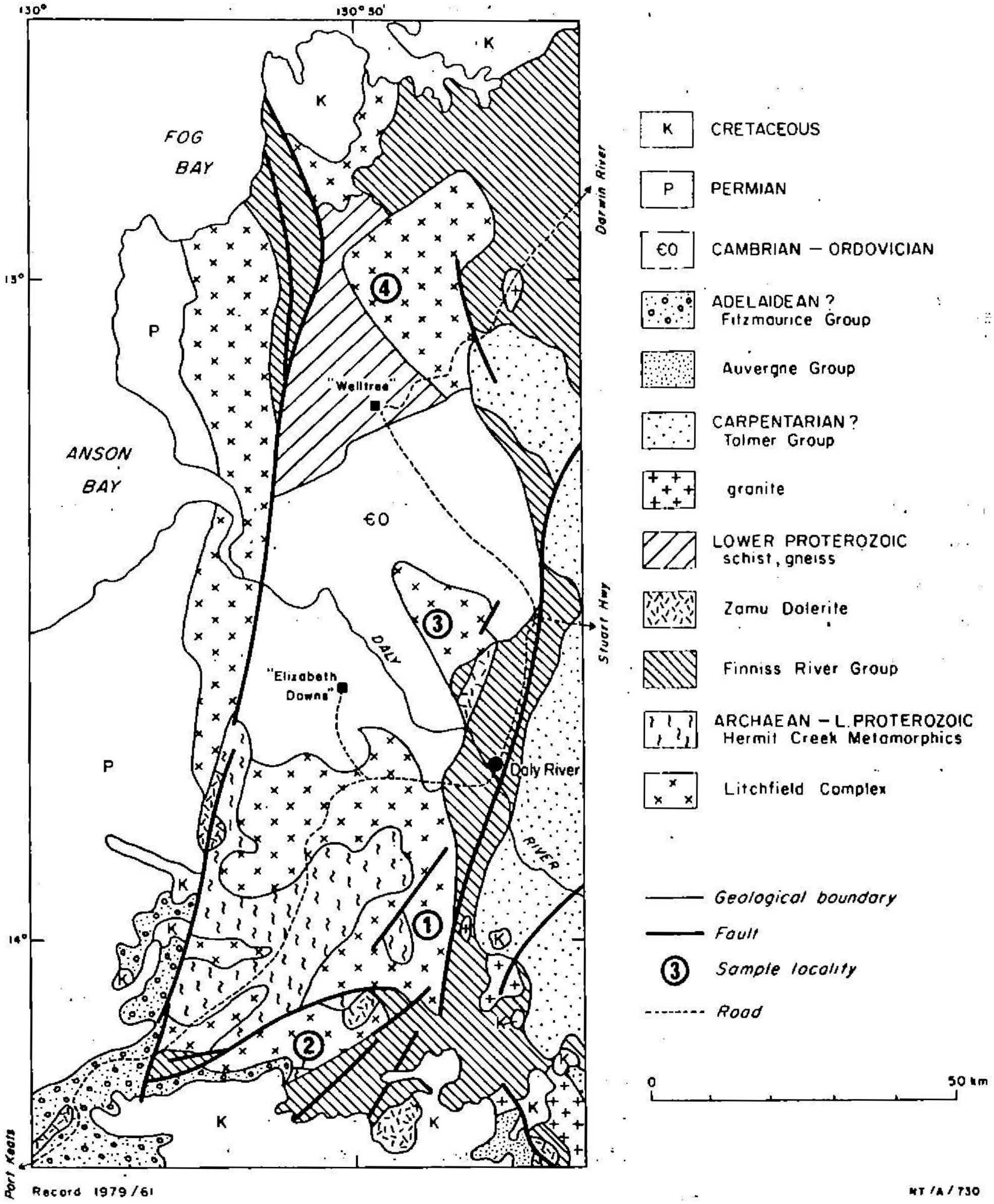


Fig. M5 Generalised geology of the Litchfield Block, showing sample locations places are cut by very coarse feldspar quartz-mica-pegmatite, with feldspar crystals up to 25 cm across.

Many features of the granodiorites of the Litchfield Complex are reminiscent of similar rocks of the migmatitic late Lower Proterozoic Nimbuwah Complex in the northeast of the Pine Creek Geosyncline. The migmatite structures, compositionally banded xenoliths and scattered outcrops of meta-sediments, and the presence of kyanite in the southern mass of the complex indicate a metamorphic origin for these rocks, and their intrusive nature suggests an age similar to that of the Nimbuwah Complex.

Copper mineralisation - Hermit Creek area

Previously unrecorded copper mineralisation was discovered near Hermit Creek, about 58 km southwest of Daly River township (locality 2, Fig. M5) during a reconnaissance survey of the Litchfield Block. The mineralisation occurs as gossaneous veinlets of malachite, azurite, and chalcocite covering an area of about 100 m^2 within altered granite (which crops out over 1000 m^2) of the Litchfield Complex. The granite intrudes the Hermit Creek Metamorphics, which are hornfelsed and extensively veined by quartz and tourmaline. A second altered granite body, apparently unmineralised, crops out about 200 m further to the east along the granite contact. Soil, rock chip, and stream sediment samples were collected from the locality and a ground IP survey by the NTGS is planned.

The discovery is significant in that it is the first report of mineral-isation within the Litchfield Complex.

ANTARCTICA

by

R.J. Tingey

STAFF: R.J. Tingey, I.A. Offe (both attached to Yilgarn Project May to September 1979), J.W. Sheraton, I.P. Black (part time), E.M. Truswell (Sedimentary Section), D.J. Ellis (University of Tasmania), P.R. James (University of Adelaide)

INTRODUCTION

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

Since 1975, BMR fieldwork and related office and laboratory studies have concentrated mainly on Enderby Land on the western edge of Australian Antarctic Territory; University scientists began collaborative studies in 1978 with BMR encouragement and assistance. The field season planned for 1978-79 was cancelled at short notice by the Antarctic Division, Department of Science and the Environment, because of logistic restraints, but will now take place in 1979-80. The fieldwork hiatus allowed laboratory work and report writing to proceed. In addition, BMR geoscientists were heavily involved in the Workshop on Antarctic Geology convened by the Geology Subcommittee of the Academy of Science's Australian National Committee for Antarctic Research (ANCAR) in May 1979. This involvement is described in some detail in the BMR Yearbook, 'BMR 79'. Sheraton's and Black's petrological, geochemical, and geochronological studies of Antarctic rocks are described in the Petrological Laboratories section of this Summary. E.M. Truswell's work is described in the Sedimentary Section's Summary.

ENDERBY LAND

A paper on the Precambrian geology of Enderby Land was completed during the year, and submitted to the Journal of the Geological Society of Australia for publication (Sheraton & others, in prep.). The exposed rocks in Enderby Land are remarkable both for their very great age - 4000 m.y. (compared with 4600 m.y. for the age of the earth) reported by Soviet geologists - and for the unique regional occurrence of metamorphic assemblages containing osumilite, a complex potassium-magnesium-iron aluminosilicate, and coexisting quartz and sapphirine. Black's geochronological studies, which are made in close collaboration with structural geology studies by Dr P.R. James of the University of Adelaide, aim to date the various major metamorphisms and deformations that have affected the Enderby Land rocks. The results have not yet produced any confirmation of the reported age of 4000 m.y., although Black has yet to sample the exact locality sampled by the Soviet scientists. The isotopic work does confirm the Archaean age of rocks in the same metamorphic complex as the Soviet sampling localities, and also the validity of the subdivision of Enderby Land into the Napier and Rayner metamorphic complexes of different age. This subdivision was originally made on geological grounds, the older Napier Complex being intersected by basic dykes that appear only as smeared-out relics in the more recently metamorphosed Rayner Complex. Subdivisions based on very similar reasoning have been applied to Precambrian metamorphic terrains in many parts of the world. Black's geochronological results have recently confirmed that the basic dykes in Enderby Land are older than the Rayner Complex and younger than the Napier Complex; furthermore there appears to be some age groupings of the dykes, and to a certain extent, these correlate with chemical groupings made by Sheraton.

The metamorphic petrology of Enderby Land has been studied by staff of the University of Tasmania and Monash University in collaboration with BMR. Preliminary results indicate very high metamorphic temperatures, moderate lithostatic pressures, and very low partial water pressures.

The Enderby Land rocks are a unique natural occurrence, on a regional scale, of certain metamorphic mineral assemblages, that by now have been extensively studied in petrological laboratories because of the insight that they provide into conditions and processes in the earth's crust.

These and other aspects of the metamorphic and igneous rocks exposed in Enderby Land are described and discussed in more detail in the various papers listed at the end of the Summary.

PRINCE CHARLES MOUNTAINS

Papers describing previous geological investigations in the Prince Charles Mountains are in press. Progress was made in compiling two 1:500 000-scale regional geological maps of the area. A base map compiled from LANDSTAT images is being used, and it is hoped to portray geological data directly upon the pictorial overview of the region provided by the imagery. The compilation involves the interpretation of new colour aerial photographs of the northern Prince Charles Mountains and as a result some previously unknown features have been detected. These include a possible lava flow that appears to overlie the well developed erosion surface that is such a notable geological feature of the area.

WORKSHOP ON ANTARCTIC GEOLOGY, MELBOURNE, MAY 1979

Seven BMR geoscientists attended the workshop on Antarctic Geology held at the School of Earth Sciences, University of Melbourne, on 17 and 18 May 1979. The workshop was co-sponsored by BMR and the host organisation, and was organised by Tingey in his capacity as Chairman of the Geology Subcommittee of ANCAR. The total attendance was more than 60, and 40 papers were presented. Preliminary abstracts were produced by BMR in a 'Record' format, and final abstracts are in press in the Journal of the Geological Society of Australia.

INTERNATIONAL ACTIVITIES

During the year an invitation was received from the West German Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) for an Australian geologist to participate in their proposed expedition (GANOVEX) to northern Victoria Land in 1979-80. The invitation was referred to the ANCAR Subcommittee for Geology, who selected D. Wyborn of BMR as the Australian representative. He will collect samples of granitoids and other rocks for detailed geochemical comparison with similar and related rocks in the Lachlan Fold Belt in Eastern Australia. The invitation, and to some extent also the proposed method of fieldwork using helicopters, resulted from contacts made with BGR geologists by Tingey at the 1977 Symposium on Antarctic Geoscience in Madison, Wisconsin, and again during a visit to BGR headquarters in Hannover in 1978. This visit was made under the auspices of the Australia-Federal Republic of Germany Science Agreement.

An exercise related to GANOVEX is planned for subsequant years as the International Geological Expedition to Northern Victoria Land. The proposal was first advanced by New Zealand geologists at the 1977 Symposium on Antarctic Geoscience, and has since received endorsement by the United States National Science Foundation, who will provide logistic support. Tingey is the Australian contact with the organisation of this project; he prepared a resume of relevant Australian research proposals for consideration at the planning meeting held in Tempe, Arizona in September 1979. First reports suggest that the meeting made no firm decisions on the various research proposals.

OTHER ACTIVITIES

Tingey is also a member of the full Committee of ANCAR and, in collaboration with members the subcommittee contributed the Geology chapter of the 1979 ANCAR document 'Australian Antarctic Research-Guidelines for Future Scientific Programs'. Tingey's chairmanship of the ANCAR Geology Subcommittee qualifies him as the Australian Member of the Geology Working Group of the Scientific Committee for Antarctic Research. During the year he joined the Editorial board of the Journal of the Geological Society of Australia as its Antarctic specialist.

The Prime Minister announced formation of the Antarctic Research Policy Advisory Committee (ARPAC) during the early part of 1979; the Director of BMR is an observer to the Committee. Briefings and information for ARPAC meetings have been provided for the Director during the year, and similar work is performed from time to time for policy divisions of the Department of National Development and other Government Departments. The information provided is a BMR input into the formulation of Commonwealth Government Antarctic Policy, both with respect to Antarctic scientific activities and to diplomatic discussions between Antarctic Treaty Nations, especially those concerned with potential Antarctic Resources.

GEOLOGICAL INVESTIGATIONS IN QUEENSLAND AND PAPUA NEW GUINEA

Supervising Geologist: K.R. Walker

MOUNT ISA-LAWN HILL PROJECT

by

G.M. Derrick & I.P. Sweet

STAFF: BMR: G.M. Derrick (Project leader); I.P. Sweet, A. Mond, R.W. Page (Geochronology, part time), P.A. Scott (Geochemistry); J. Stirzaker, A. Retter, G. Butterworth (draftsmen); J. Pollard (field assistant)

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

AIMS: Research into the Precambrian rocks of the Cloncurry Complex in order to delineate areas potentially favourable for mineralisation, to revise the stratigraphy and structure, and to reconstruct the sedimentary, igneous, and metamorphic history of the region.

RELATED INVESTIGATIONS: Geochronology and geochemistry (see Metalliferous Laboratories report); Duchess Geology.

FIELD ACTIVITIES

Introduction Field work in 1979 was directed to final checking and completion of all 1:100 000 Sheet areas in the region, and to the resolution of differences of interpretation between the Mount Isa and Duchess Projects. Members of both projects inspected many critical and problem areas throughout the region, and the results of this inspection are presented in the section 'Mount Isa and Duchess Projects: joint inspection of the Mount Isa/Duchess region'.

In the Mount Isa/Lawn Hill area, supplementary traverses were made by project staff in MOUNT OXIDE, MAMMOTH MINES, LAWN HILL, ALSACE, MYALLY, COOLULLAH, OBAN, and MOUNT ISA 1:100 000 Sheet areas. Sweet and Hutton examined sections of the Mount Isa Group, and supervised a stratigraphic drilling program in LAWN HILL. Location of the various sheet areas is shown in Frontispiece 2; a generalised stratigraphy of the Mount Isa/Lawn Hill region is shown in Fig. M6.

Supplementary traverses

The Fiery Creek Volcanics were examined west of Sandy Creek in north-eastern MOUNT OXIDE, where they consist of a single massive sheet of white to pinkish-brown, streakily flow-banded rhyolite. They overlie Quilalar Formation with slight angular unconformity, and the conglomerate and sandstone which form the basal part of the Fiery Creek Volcanics east of Sandy Creek are absent.

Field relations between the Fiery Creek Volcanics and the Weberra Granite are unclear; R. Page collected samples of both units to date them by the U-Pb zircon method. The Granite intrudes the Quilalar Formation, which is also cut by trachyte and quartz-feldspar porphyry dykes, but relations with the Fiery Creek Volcanics are not known.

The McNamara Group was re-examined in several places in western MOUNT OXIDE in an attempt to delineate its stratigraphy and structure more accurately. South of Police Creek the McNamara Group is strongly deformed, and it is difficult to distinguish between the Paradise Creek and Lady Loretta Formations. However, all formations have now been identified, and a number of tight folds and several strike faults delineated. A carbonaceous pyritic siltstone,

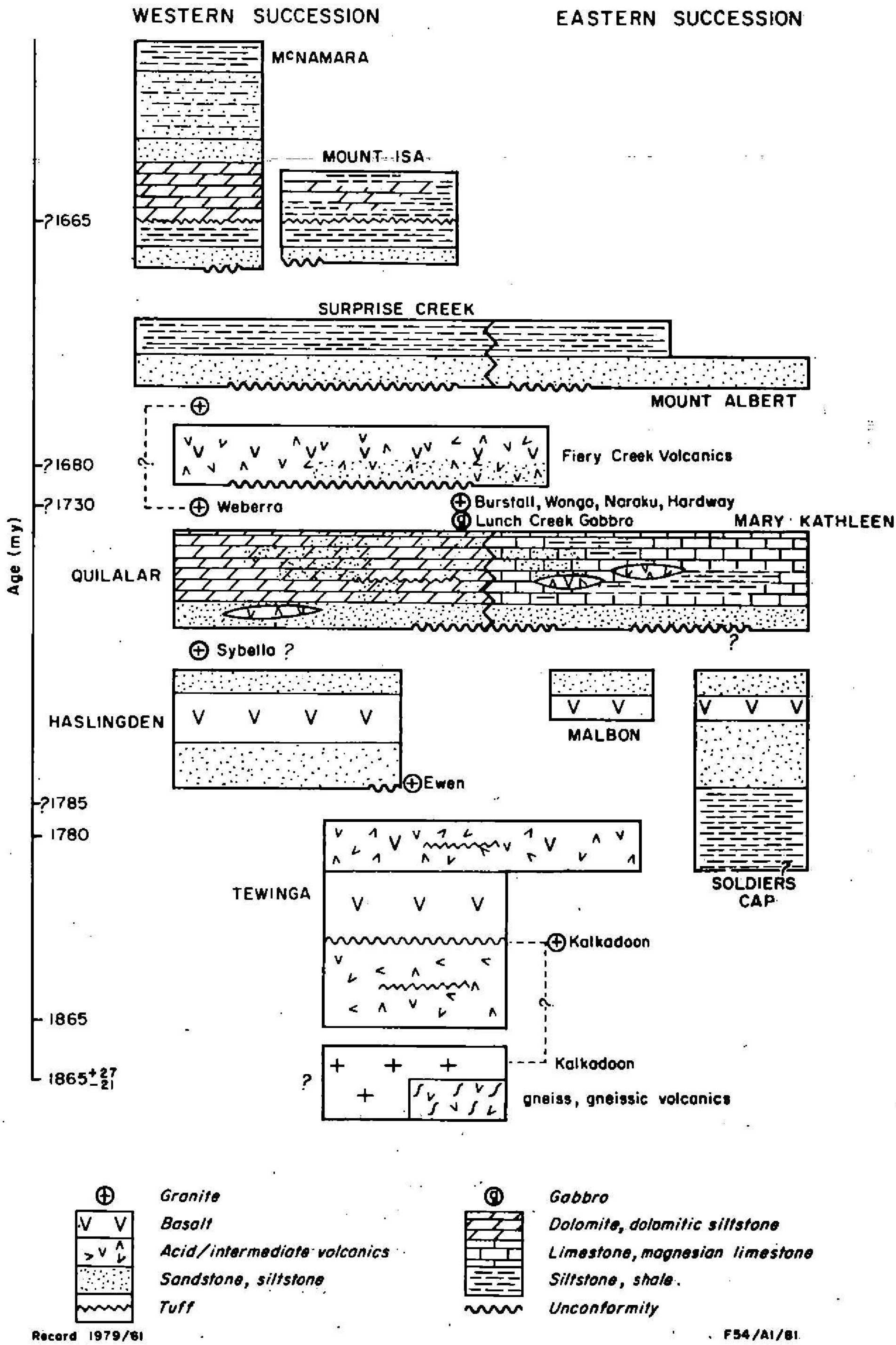


Fig M6 Generalised stratigraphy of the Mount Isa-Lawn Hill region

previously thought to be a lens within the Lady Loretta Formation, is now believed to be an infaulted slice of Gunpowder Creek Formation. In southwestern MOUNT OXIDE two cherts bands are present in the Paradise Creek Formation - the lower one is the Mount Oxide Chert Member and the upper one is a previously unmapped chert about the same thickness as the named member, but about 50 m above it (see Table M1).

In MYALLY, in the Ewen Block, well-preserved, low-grade ignimbrites of the Leichhardt Metamorphics were sampled by R. Page for U-Pb zircon dating. The volcanics are overlain unconformably by conglomerate, arkose, and quartzite of the Myally Subgroup (part of the Haslingden Group), which is overlain conformably by Quilalar Formation. Thin bands of green tuff or tuffaceous siltstone in the latter correlate with similar tuff bands in ALSACE to the south. Along the western edge of the Ewen Block near Dynamite Creek, the Eastern Creek Volcanics and Myally Subgroup rest unconformably on Ewen Granite. The former contact is marked by a thin basal arkose and feldspathic sandstone 10 to 20 m thick, overlain by low-grade, well-preserved basalt; the basal Myally Subgroup, however, is an 80 m-thick sequence of coarse arkose and grit, in places nearly indistinguishable from the underlying, weathered Ewen Granite. Along the eastern edge of the Ewen Block basal arkose and pebble beds of the Myally Subgroup rest unconformably on the ?Leichhardt Metamorphics.

To the southeast, in COOLULLAH, the metamorphic grade of Tewinga and Mary Kathleen Groups increase eastwards. The Magna Lynn Metabasalt contains thick sequences of pebbly arkose and conglomerate which are absent in the unit farther south. The Corella Formation contains basal skarn lenses which may be higher-grade equivalents of magnetite-bearing sediments in the Corella Formation elsewhere.

Mount Isa Group

Sections of the Mount Isa Group were examined briefly in the Crystal Creek, Mount Isa, and Oban areas in an effort to determine the Group's relation to the McNamara Group. We agree with Cavaney (1975) that the lower Mount Isa Group (Warrina Park Quartzite, Moondarra Siltstone, Breakaway Shale) can be confidently correlated with the Torpedo Creek Quartzite and Gunpowder Creek Formation in the McNamara Group. It is also reasonable to correlate the Breakaway chert marker with the Mount Oxide Chert Member at the base of the

Paradise Creek Formation. Cavaney (1975) correlated the Native Bee chert marker with his 'Intermediate member', but it could be equivalent to the younger chert bed observed in southwestern MOUNT OXIDE (see above), which we believe is below the level of the 'Intermediate member'. There are also similarities between the Native Bee Siltstone and the lower part of the Paradise Creek Formation - both consist of interbedded dolomite and dolomitic siltstone deposited in low-energy environments. The Urquhart Shale could be equivalent to the upper part of the lower Paradise Creek Formation rather than to the Esperanza Formation as believed by Cavaney. Whichever correlation is accurate, the Lady Loretta ore horizon is probably younger than the Mount Isa mineralisation, rather than equivalent to it as suggested by Plumb & Sweet (1974). The upper (and higher-energy) part of the Paradise Creek Formation and younger units in the McNamara Group may therefore be equivalent to the Spear Siltstone and other units in the Mount Isa Group. These correlations are summarised in Table M1.

Stratigraphic drilling

A three-hole program of diamond-drilling, totalling 1127 m, was carried out using a GSQ drilling rig. Two holes were sited to provide a complete section of the McNamara Group below the Esperanza Formation in the centre of the Kamarga Dome, in LAWN Hill; outcrop of these units - the Paradise Creek and Gunpowder Creek Formations - is poor. Low-grade zinc mineralisation is currently being investigated by mining companies in equivalent sequences in an adjacent fault block.

The third hole was sited in basal Lady Loretta Formation in GREGORY DOWNS. It was drilled to obtain fresh samples of an interval of poorly exposed, limonite-cemented chert breccia. Unfortunately, altered rock was penetrated to a depth of over 200 m, and apart from a few metres of siltstone and stromatolitic chert, little core was recovered.

All core recovered from the three holes will be logged and studied, and stored in Brisbane; a Record of the results will be issued.

TABLE M1. Correlations between McNamara and Mount Isa Groups

McNAMARA GROUP	MOUNT ISA GROUP
Lawn Hill Formation	
Termite Range Formation*	
Riversleigh Siltstone	
Shady Bore Quartzite	
——?——?——	
Lady Loretta Formation	?
	——?——?——?——?——
——?——?——	Magazine Shale, and Spear and Kennedy Siltstones
Esperanza Formation	
——?——?——	Urquart Shale
Paradise Creek Formation	Native Bee Siltstone
unnamed chert member	Native Bee chert marker
Mount Oxide Chert Member	Breakaway chert marker
Gunpowder Creek Formation	Breakaway Shale
	Moondarra Siltstone
Torpedo Creek Quartzite Member	Warrina Park Quartzite
Surprise Creek Formation (not part of either group)	

*previously Quartzite

OFFICE ACTIVITIES

Maps

First Edition 1:100 000: PROSPECTOR is in press; KENNEDY GAP and QUAMBY are being edited.

Preliminary Edition 1:100 000: LAWN HILL was issued; ALSACE is with the printers, and CARRARA RANGE REGION and RIVERSLEIGH are in preparation. A Preliminary Second Edition of CLONCURRY was issued.

Field compilation: compilation of GREGORY DOWNS, RIVERSLEIGH, BOWTHORN, MUSSELBROOK, and MOUNT OXIDE is complete; compilation of MAMMOTH MINES, MYALLY, and COOLULLAH is in progress.

Reporting of results:

A Record (1979/45) describing GREGORY DOWNS and RIVERSLEIGH completion sheets was issued; Records describing KENNEDY GAP (1979/24) and QUAMBY (1979/56) are with the editors, and Records on LAWN HILL, ALSACE, and on the South Nicholson Group in BOWTHORN, MUSSELBROOK, and CARRARA RANGE REGION are in preparation.

The Map Commentary for the MARRABA First Edition is with the editors; a paper was written, with K.A. Plumb, on 'Proterozoic of Northern Australia' for a volume entitled 'Precambrian Shields of the Southern Hemisphere', edited by D.R. Hunter and currently in press. A paper by Hutton & Sweet defining the Kamarga Volcanics, a new unit in LAWN HILL, is with the editors, and a paper by Derrick, Wilson & Sweet defining the Quilalar and Surprise Creek Formations is in preparation.

Lectures were presented by Sweet (to BMR) on results of 1978 field work, and by Derrick (to BMR symposium) on red-bed environments and rift structures in the MAMMOTH-MOUNT OXIDE area.

Miscellaneous

Derrick completed his Ph.D. studies in the Mary Kathleen region, and was awareded the Ph.D. degree in September, 1979. He also completed notes describing the geology of Australia, to accompany the 1:10 000 000 General

Geology map of Australia in the Atlas of Australian Resources. He attended a seminar in Sydney presented by Dr Amstutz on 'Ores in Sediments', and part of the International Uranium Symposium held in Sydney during June. Sweet attended an AMF course, "Geophysics for Geologists", in Adelaide in March.

Dr L. Wyborn continued with geochemical and petrographic studies on Mt Isa granites; geochemical studies of acid and basic volcanics, sediments and gossans continued, in conjunction with the BMR laboratory and AMDL. Liaison with P. Scott continued on the geochemistry of MAMMOTH MINES. Stromatolites from the Quilalar Formation in MOUNT OXIDE were studied jointly by M.R. Walter and Dr I.N. Krylov (Geological Institute, Moscow) - see under Palaeontology Section.

WESTMORELAND PROJECT

by

I.P. Sweet

STAFF: I.P. Sweet

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

During the year, a Bulletin was prepared, combining information contained in three previously issued Records (1975/88; 1976/34 and 1978/32). SEIGAL and HEDLEYS CREEK First Editions have been drawn, and will be printed in 1980. The coloured Second Edition of the Westmoreland 1:250 000 Sheet is being printed, and Explanatory Notes for this sheet have been prepared.

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

DUCHESS PROJECT

by

D.H. Blake

STAFF: D.H. Blake (Project leader), R.J. Bultitude, A.I. Jaques (part time), P.J.T. Donchak (GSQ), G.A. Young (Draftswoman)

AIMS: The aims of the Duchess Project are to carry out field research which will result in the production of geological maps at 1:100 000 scale, accompanied by reports, of the Precambrian parts of the Duchess and Urandangi 1:250 000 Sheet areas, and to review the stratigraphy, structure, geological history, and mineral potential of the area. The Precambrian rocks exposed belong to the Cloncurry Complex, as defined by Carter, Brooks, & Walker (1961, BMR Bulletin 51), and are hosts to copper, silver, cobalt, gold, lead, zinc, tungsten, and uranium mineralisation.

INTRODUCTION

Office work during the year involved map compilation, airphoto interpretation, petrographic studies, and report writing. The data-Record for the DUCHESS 1:100 000 Sheet area, accompanied by the Preliminary map, was completed and issued as BMR Record 1978/112. Photoscale (about 1:26 000) compilation sheets for the 1:100 000 Sheet areas mapped in 1978 - ARDMORE, MOUNT MERLIN, SELWYN, MOUNT ANGELAY - were completed and are available to the public through the AGPS. Drafting of the 1:100 000-scale Preliminary Editions for these Sheet areas is in progress and the first drafts of the accompanying data Records have been prepared. The maps and reports are expected to be completed and issued as BMR Records by early 1980.

From 6 to 10 November 1978 Blake attended an AMF course on 'Tin - geology and exploration' in Adelaide, and in April 1979 he took part in a 2-day excursion of the Olary Block organised by the Geological Survey of South Australia and a 6-day excursion of the Broken Hill Block run by geologists from the New South Wales Geological Survey. As well as working on the Duchess Project, Blake supervised the Northern Territory & Antarctica Subsection up to the end of June.

Systematic geological field studies of the Precambrian parts of the Duchess and Urandangi 1:250 000 Sheet areas was completed in 1978. Blake, Bultitude, and Donchak revisited the area in July-September 1979 to check critical field relationships, obtain further data for some rock units, and to collect samples for U-Pb zircon geochronology.

A.I. Jaques began a microprobe study of amphibolites and calc-silicate rocks of the area to help the understanding of the regional metamorphism in the area.

<u>DUCHESS AND DAJARRA 1:100 000 SHEET AREAS</u> by D.H. Blake and R.J. Bultitude

The main results of the 1979 field work in the two sheet areas are as follows.

(1) Samples of acid volcanics, gneisses, and granites were collected for U-Pb zircon geochronology.

(2) Bands of distinctive types of granite, previously mapped as phases of Kalkadoon Granite, extend across the boundary between the two Sheet areas and intrude acid gneisses mapped as undivided Tewinga Group.

(3) Gneissic and schistose rocks mapped as undivided Tewinga Group east of Dajarra township include a thick sequence of interlayered metamorphosed basic and acid volcanic rocks.

(4) Quartz-feldspar porphyries mapped as Standish volcanics overlie granodiorite/diorite, mapped as a phase of Kalkadoon Granite (Pgk_d), east of Wills Creek in DAJARRA.

(5) The presence of metamorphosed acid volcanics, probably both tuffs and lavas, within the Corella Formation in northeast DUCHESS was confirmed.

(6) Wills Creek Granite, a pink and generally leucocratic medium to coarse biotite granite which intrudes Standish volcanics, is much more extensive than previously thought, and extends from south to north across both sheet areas.

<u>ARDMORE 1:100 000 SHEET AREA</u>, by R.J. Bultitude

The Precambrian rocks in ARDMORE (Fig. M7) can be broadly divided into three northerly-trending belts, each containing abundant metabasalt. The eastern belt contains units that extend from the adjoining DAJARRA and DUCHESS

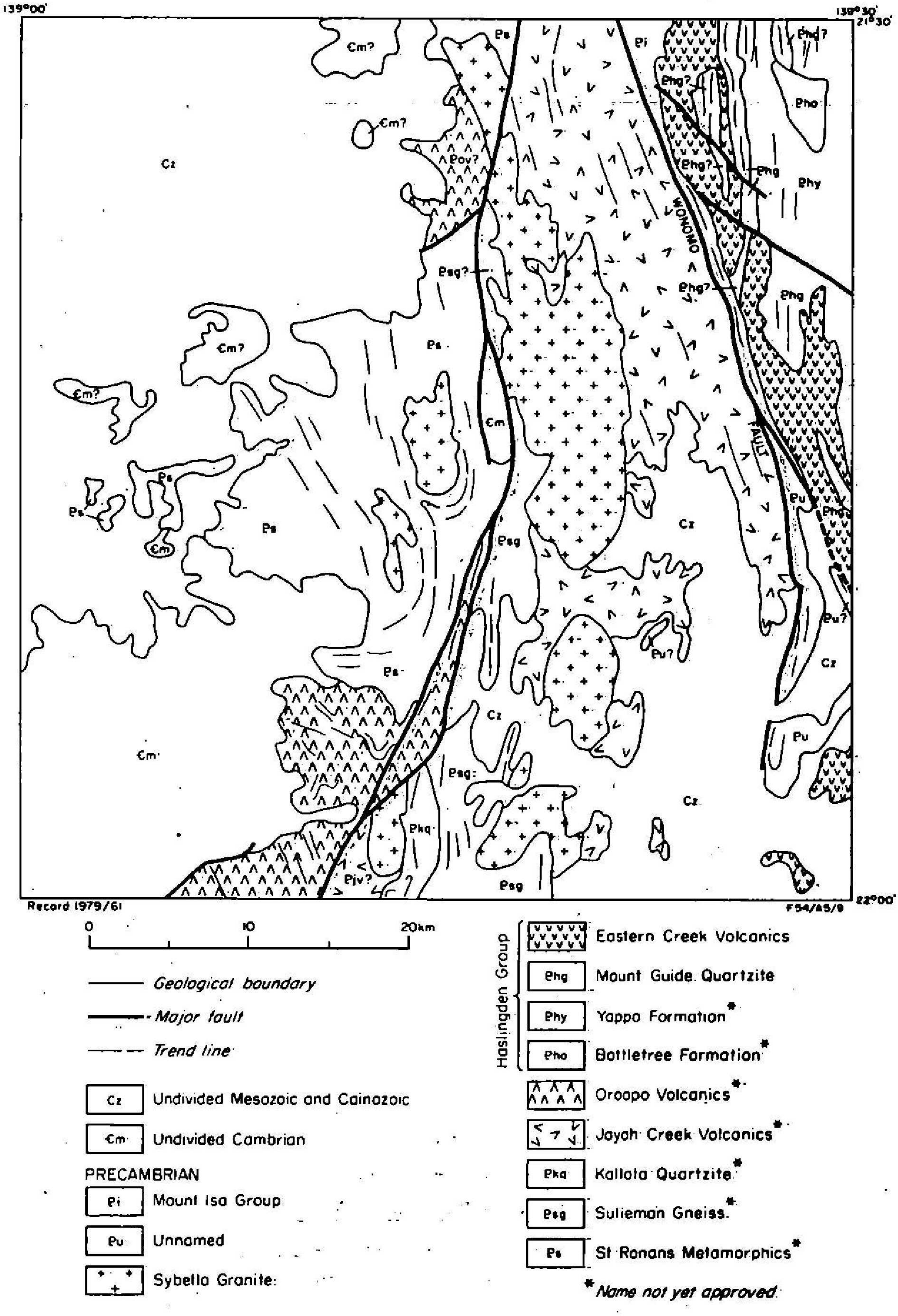


Fig. M7 Geology of the Ardmore 1:100 000 Sheet area.

areas to the east and northeast, but the central and western belts are characterised by a lack of distinctive marker units that can be correlated unequivocally with units mapped elsewhere in the Mount Isa region. The predominantly metabasalt units in the central and western belts were tentatively assigned to the Eastern Creek Volcanics; this relationship is shown on released photo-scale field compilation sheets.

The oldest rocks in the eastern belt are the poorly exposed recrystallised felsic volcanics, interpreted to be mainly finely banded tuffs, and interlayered metagreywacke and sericitic and feldspathic meta-arenite, exposed in the northeast and assigned to the Bottletree Formation. They are conformably overlain by, and are probably partly diachronous with, the Yappo Formation, which consists mainly of regionally metamorphosed greywacke and greywacke-conglomerate. Most of the pebbles in this formation are of extensively recrystallised felsic volcanics. The Yappo Formation is broadly equivalent to the lower Mount Guide Quartzite mapped in MOUNT ISA and MARY KATHLEEN. It is conformably overlain by pebbly quartzite and by quartzose, feldspathic, and sericitic meta-arenite of the Mount Guide Quartzite, a unit that has been folded about northerly-trending axes, and intruded by numerous metadolerite dykes.

The Mount Guide Quartzite is overlain, apparently concordantly, by the Eastern Creek Volcanics, a sequence of mainly non-schistose amygdaloidal metabasalt lava flows and interlayered lenses of epidotic quartzite, pebbly meta-arkose, and quartzose and feldspathic meta-arenite, metamorphosed greywacke-conglomerate and pebbly greywacke, and grey to pink quartzitic rocks which may represent recrystallised felsic tuffs or tuffaceous metasediments. Most clasts in the conglomeratic rocks are of non-schistose metabasalt and little-altered felsic volcanics. The unit is intruded by numerous metadolerite dykes and is overlain, apparently unconformably, by a sequence consisting of sericitic, feldspathic, and quartzose meta-arenite. This sequence, assigned to the Warrina Park Quartzite, the basal unit of the Mount Isa Group, appears to grade up into poorly exposed, low-grade regionally metamorphosed, thin-bedded pyritic, micaceous, and siliceous siltstone, dolomitic siltstone, dolomite, limestone, and pyritic shale, mapped as Moondarra Siltstone. The Moondarra Siltstone is overlain, apparently conformably, by the Breakaway Shale, consisting mainly of blue-grey to black, ?carbonaceous shale, commonly containing numerous pyrite casts. Because of their limited extent these formations of the Mount Isa Group are not shown separately.

An unnamed sequence exposed in the southwestern part of the eastern belt consists mainly of quartzose, feldspathic, and sericitic meta-arenite containing some pyrite casts, overlain by micaceous metasiltstone. Gossanous outcrops confined mainly to certain beds are common in the upper part of the sequence. Originally mapped as possible lower Mount Isa Group, the sequence extends into adjacent DAJARRA where it has been tentatively assigned to the Myally Subgroup, because it appears to be conformable on mafic metavolcanics and interlayered metasediments mapped as Eastern Creek Volcanics.

The central belt is bounded to the east and west by faults. Rocks exposed in this belt appear to be similar to those described west of the Mount Isa Fault in MOUNT ISA to the north by Hill & others (BMR Record 1975/175) where they have been mapped mainly as Haslingden Group. However, because of some uncertain stratigraphic relationships, a lack of distinctive marker units, an absence of reliable isotopic age dates, and the consequent possibility that they are not equivalent to the Haslingden Group, most units in the central (and also the western) belt are now referred to new formations. The Sulieman Gneiss*, most extensively exposed in the southwest, is tentatively regarded as the oldest unit in the belt. It consists mainly of interlayered hornblende schist, quartz+biotite+feldspar±garnet±muscovite gneiss and augen gneiss, and glassy quartzite, muscovite quartzite, and feldspathic quartzite; also present are some banded calc-silicate gneiss (commonly garnetiferous), para-amphibolite, and numerous extensively deformed pegmatite veins that are generally concordant with the foliation. The sequence is intruded by foliated to non-foliated granite, by probably related undeformed pegmatite veins, and also by rare dykes and pods of little-altered dolerite containing primary biotite.

The transition from Sulieman Gneiss westwards to a sequence of glassy quartzite, muscovite quartzite, feldspathic quartzite, and minor hornblende schist, mapped as Kallala Quartzite*, appears gradational over a distance of a few metres.

The eastern part of the central belt consists of the Jayah Creek Volcanics*, a sequence of predominantly schistose amygdaloidal and massive amphibolitic metabasalt and numerous metasedimentary lenses. These lenses consist mainly of sericitic, feldspathic, and quartzose meta-arenite, quartz+muscovite+biotite±feldspar schist and gneiss, quartzite, and muscovite

* Name not yet approved.

quartzite; minor rock types present include para-amphibolite, calc-silicate rocks, recrystallised impure limestone, and quartz-biotite-muscovite schist containing cordierite poikiloblasts. The Jayah Creek Volcanics are intruded by granite, numerous metadolerite dykes and pegmatite veins, and rare quartz-feldspar porphyry dykes. The unit appears to have concordant contacts with Kallala Quartzite and Sulieman Gneiss.

A sequence of poorly exposed cross-bedded quartzose meta-arenite and laminated to thin-bedded metasiltstone and shale preserved in the keel of a syncline in the southern part of the central belt is tentatively correlated with the unnamed unit of the eastern belt (possibly Mount Isa Group). Contacts with adjacent Jayah Creek Volcanics were not observed, but the two units appear to be separated by faults and a possible metamorphic unconformity.

The metamorphic grade in the central belt appears to increase westwards from about middle greenschist facies to about middle amphibolite facies. The highest-grade rocks appear to be those exposed in the southwest and mapped mainly as Sulieman Gneiss and Kallala Quartzite. The western part of the belt is extensively intruded by the Sybella Granite, the main phase of which appears to be post-tectonic and not related to the regional metamorphism because it commonly cuts across the foliation in the country rocks at high angles.

In the western belt in the far south, little-metamorphosed non-schistose basalt similar to that in the eastern belt, with intercalated meta-arenite and metasiltstone, is overlain in one place by, and elsewhere apparently interlayered with, pebbly quartzose meta-arenite, meta-arkose, calcarenite, and limestone. The volcanic and sedimentary sequence here is assigned to the Oroopo Volcanics*. The metamorphic grade increases northwards to about lower amphibolite facies in the centre of the belt, where the Oroopo Volcanics appear to be underlain concordantly by the St Ronans Metamorphics*, which consist mainly of interlayered recrystallised felsic volcanics, schistose amphibolite, amygdaloidal metabasalt, and quartz+muscovite+biotite$\pm$andalusite schist. This unit is extensively intruded by granite, pegmatite veins, and amphibolitic metadolerite.

Granitic rocks restricted to the central and western belts are mapped as Sybella Granite. The main phase, a non-foliated to foliated, coarse-grained, xenolithic, porphyritic biotite granite, intrudes small masses of strongly foliated medium-grained hornblende-biotite granodiorite, gneissic granite, and augen gneiss, and minor xenolithic diorite. All these phases are cut by veins and small bodies of non-foliated medium-grained biotite granite and biotite leucogranite. Another phase, exposed mainly in the western belt, consists of non-foliated, medium-grained to pegmatitic biotite-muscovite leucogranite. In most places bedding and foliation in adjacent country rocks show little apparent disruption by the intrusion of granite, and contact metamorphic effects appear to be restricted to a hornfels zone within 5 m or so of granite contacts.

The Precambrian rocks are unconformably overlain in the west by flat-lying to gently dipping rocks of the Georgina Basin succession, of mainly Middle Cambrian age. Rocks of the Beetle Creek Formation within the succession are commonly phosphatic, and some significant deposits of rock phosphate have been found by exploration companies.

Scattered outcrops, mainly mesa cappings, of flat-lying, poorly consolidated conglomeratic and finer-grained sedimentary rocks are mapped as Mesozoic. Cainozoic deposits consist mainly of laterite and unconsolidated gravel, sand, silt, and clay.

SELWYN REGION (SELWYN AND MOUNT MERLIN 1:100 000 SHEET AREAS) by D.H. Blake

In spite of the relatively detailed field investigations in 1978 and some follow-up work in 1979, several uncertainties regarding the stratigraphy of the Selwyn region (Fig. M8) still exist. For instance, it has yet to be established which are the oldest rocks in the area, and whether or not there are major unconformities within the Precambrian sequence.

In the northwest the stratigraphic units generally dip steeply east and young east. The most westerly unit exposed, mapped as Argylla Formation, consists of metamorphosed acid volcanics and associated feldspathic metasediments. To the east these rocks are overlain by and interfinger with the Marraba Volcanics, a unit of metamorphosed basic volcanics, including some amygdaloidal lava, and interlayered metasediments. The succeeding Mitakoodi Quartzite is made up mainly of quartzose to feldspathic meta-arenites. The conformably overlying Answer Slate, which consists of phyllite, schist, and metasiltstone as well as slate, passes eastwards into mostly fine-grained and variably calcareous metasediments mapped as Staveley Formation. This formation is tentatively taken to include sequences of interbedded arenites and siltstones (Pks_x) showing well-preserved convolute bedding, cross-bedding, and ripple marks. One such sequence in the east appears to be less metamorphosed and less

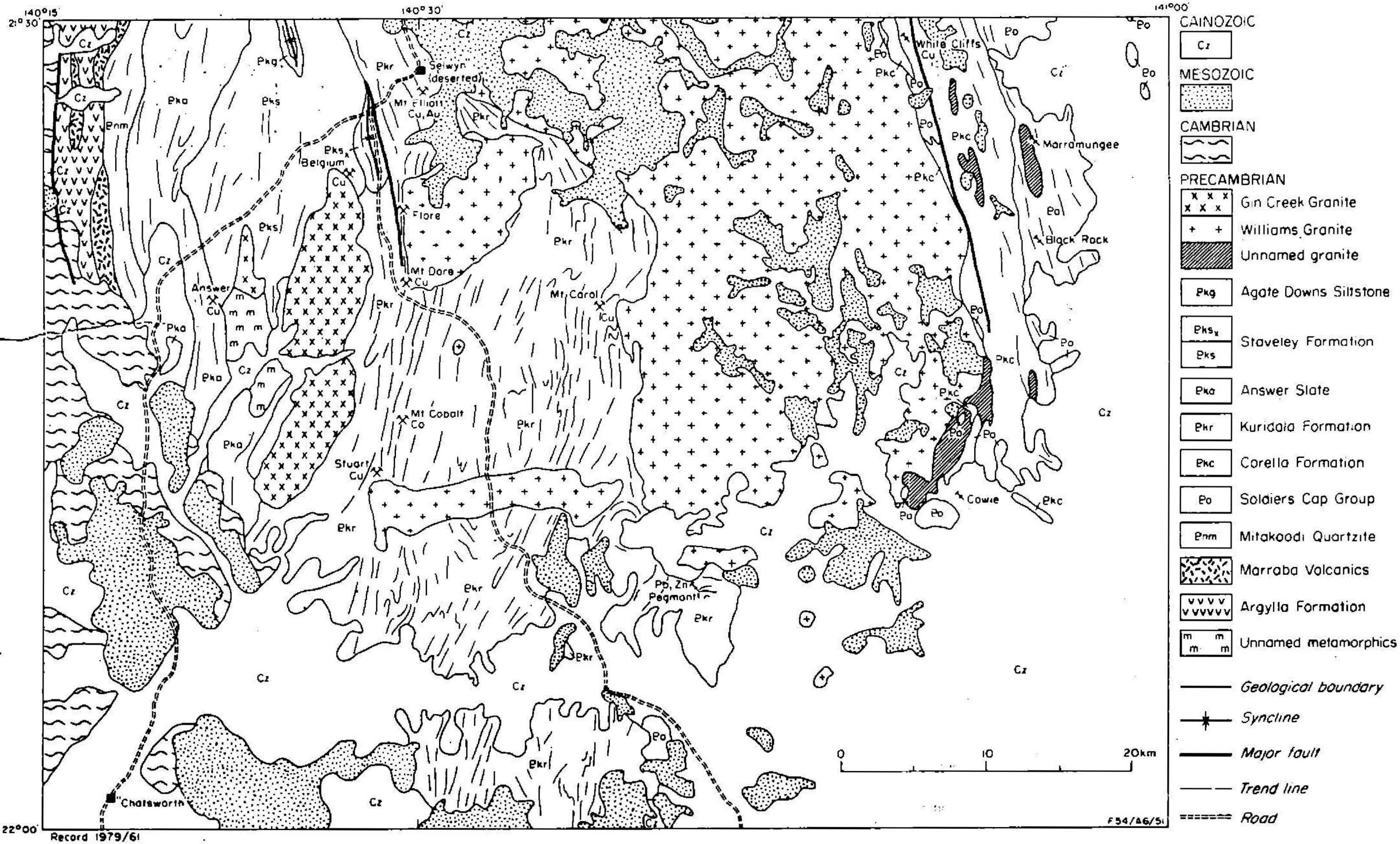


Fig. M8 Geology of the Selwyn and part Mount Merlin 1:100000 Sheet areas deformed (affected by one rather than two deformations), indicating that it may be separated from the adjacent Kuridala Formation by a major unconformity.

The Staveley Formation is overlain conformably in the north by the Agate Downs Siltstone, a unit of phyllitic metasiltstone and fine quartzite occupying the central part of a northerly plunging syncline. The Kuridala Formation is made up predominantly of mica schist and schistose metagreywacke, but also includes graphitic slate, other metasediments, and minor acid and basic metavolcanics; mica schist commonly contains porphyroblasts of andalusite ± garnet ± staurolite.

The Answer Slate, Kuridala Formation, and at least parts of the Staveley Formation are regarded as correlatives. Facing evidence, bedding trends, and deformed basic intrusions show that all three formations are tightly to isoclinally folded on both major and minor scales. The Staveley Formation appears to occupy the central part of a major synclinorium.

Unnamed metamorphic rocks in the northwest, partly enclosed by Answer Slate and Staveley Formation, consist mainly of migmatitic muscovite-biotite-quartz-feldspar gneiss and schist veined by granite, aplite, and pegmatite. Because of differences in composition they do not appear to be the more metamorphosed equivalents of adjacent metasediments, but instead may represent rocks from deeper in the crust carried to their present position during emplacement of Gin Creek Granite. This granite, which intrudes Answer Slate, Staveley Formation, and Kuridala Formation as well as the unnamed metamorphic rocks, ranges from foliated to non-foliated, consists of biotite and tourmaline-muscovite granites, and commonly contains large inclusions of country rocks.

The main rock types of the Soldiers Cap Group, which crops out in the eastern part of the region, are schist and gneiss representing metamorphosed and partly migmatitic quartzofeldspathic and greywacke-type sediments. Subordinate rock types include amphibolite, some of which is garnetiferous, derived from amygdaloidal basic lava; quartzite; calc-silicate rocks; and banded iron formation. The relationship of the Soldiers Cap Group to the adjacent Corella Formation, which is formed mainly of banded to brecciated calc-silicate rocks, is uncertain because of structural complexities and lack of facing evidence; the presently favoured interpretation is that the two units form a conformable and locally interfingering sequence of which probably the Corella Formation part is generally the younger.

The Soldiers Cap Group and Corella Formation, and also the Kuridala Formation to the west, are intruded by Williams Granite, the main types of which are porphyritic and non-porphyritic biotite and hornblende-biotite granites. The Williams Granite is generally not foliated, and cuts across fold structures in adjacent rocks; hence it is considered to be post-tectonic. Unnamed granite, which intrudes the Soldiers Cap Group and Corella Formation, is generally foliated, and is probably syntectonic.

Northerly trending metadolerite and amphibolite sills, dykes, and pod-like bodies intrude all the Precambrian units except Agate Downs Siltstone, unit Pks$_x$ of the Staveley Formation, and the granites; they predate the main folding event. The youngest basic intrusions are post-tectonic east-trending dolerite dykes which cut granite and older rocks.

The Phanerozoic rocks of the region comprise Cambrian sediments of the Burke River Outlier sequence, which overlie Precambrian rocks in the west; flat-lying Mesozoic sediments, correlated with the Eromanga Basin sequence to the east, which are widespread on summit surfaces; and unconsolidated Cainozoic sediments, most extensive in the south and east.

The Selwyn region contains copper, cobalt, gold, tungsten, lead, zinc, and uranium mineralisation. Total production amounts to over 26 000 tonnes of copper, 778 tonnes of cobalt, and nearly 2 000 kg of gold. Most of the copper mineralisation is in the Kuridala Formation, mainly in graphitic slate. The largest copper deposit, at the Mount Elliott mine near Selwyn, also produced most of the gold recovered from the area. Cobalt has been produced at the Mount Cobalt mine, situated in the Kuridala Formation next to a metadolerite intrusion. Minor tungsten mineralisation is known in the same general area and a uranium prospect is located 5 km to the north, again within the Kuridala Formation. Banded iron formation at Pegmont prospect, in Kuridala Formation, and at prospects to the northeast, in Soldiers Cap Group, contain subeconomic concentrations of lead, zinc, and copper. Stratabound quartz-hematite-magnetite bodies, present in all of the Precambrian units in the northwest, are locally anomalously rich in copper and gold. Because of the known mineralisation, some of which was previously economic, and also because of geological similarities with the Broken Hill area of western New South Wales, the region has considerable appeal for exploration companies.

MOUNT ANGELAY 1:100 000 SHEET AREA by P.J.T. Donchak

The oldest unit of the Precambrian sequence exposed in MOUNT ANGELAY (Fig. M9) is mapped as Soldiers Cap Group. This unit consists of mica schist, gneiss, meta-arenite, quartzite, banded ironstone, metabasalt, ortho-amphibolite, and minor calc-silicate rocks. Pelitic rocks contain locally abundant porphyroblasts of garnet, sillimanite, andalusite, cordierite, and staurolite produced during amphibolite-grade regional metamorphism. Steep dips and northerly trends predominate, and up to three generations of folding have been recognised.

Apparently overlying the Soldiers Cap Group are bedded and brecciated calc-silicate rocks of the Corella Formation. This formation locally contains abundant scapolite, garnet, and clinopyroxene indicative of amphibolite-grade metamorphism. Bedding dips are steep and at least two generations of folding are evident. The presence of abundant calc-silicate breccia and complex faulting in contact zones obscures the relationship between the Corella Formation and the Soldiers Cap Group. No unequivocal evidence has been found for an unconformity between the two units, and interlayering of calc-silicate rocks and schists at some contacts suggests a conformable and locally interfingering relationship.

Rocks mapped as unit Pkc_x of the Corella Formation in the northwest consist of fine-grained calcareous and feldspathic arenites, fine-grained calcareous granofels, and massive and minor stratabound breccia. These rocks appear generally similar to but less metamorphosed than the Corella Formation to the east (from which they are separated by a series of northeast-trending faults) but lack the amphibole common in the latter. They may be equivalent to Corella Formation unit Pkc_3 in MALBON to the west and unit Pks_x of the Staveley Formation in the Selwyn region to the south.

Facing evidence suggests that the Pkc_x rocks conformably underlie slate and minor arenite of the Marimo Slate and cross-bedded feldspathic arenite of the Roxmere Quartzite. The occurrence of identical bedded breccias in the Roxmere Quartzite and unit Pkc_x suggests a similar provenance and depositional environment. Facing in the cross-bedded Mick Creek Sandstone Member of the Marimo Slate in the north indicates that this unit overlies Pkc_x.

In the west, mica schist, meta-arkose, metagreywacke, phyllite, and slate of the Kuridala Formation are faulted against Corella Formation to the

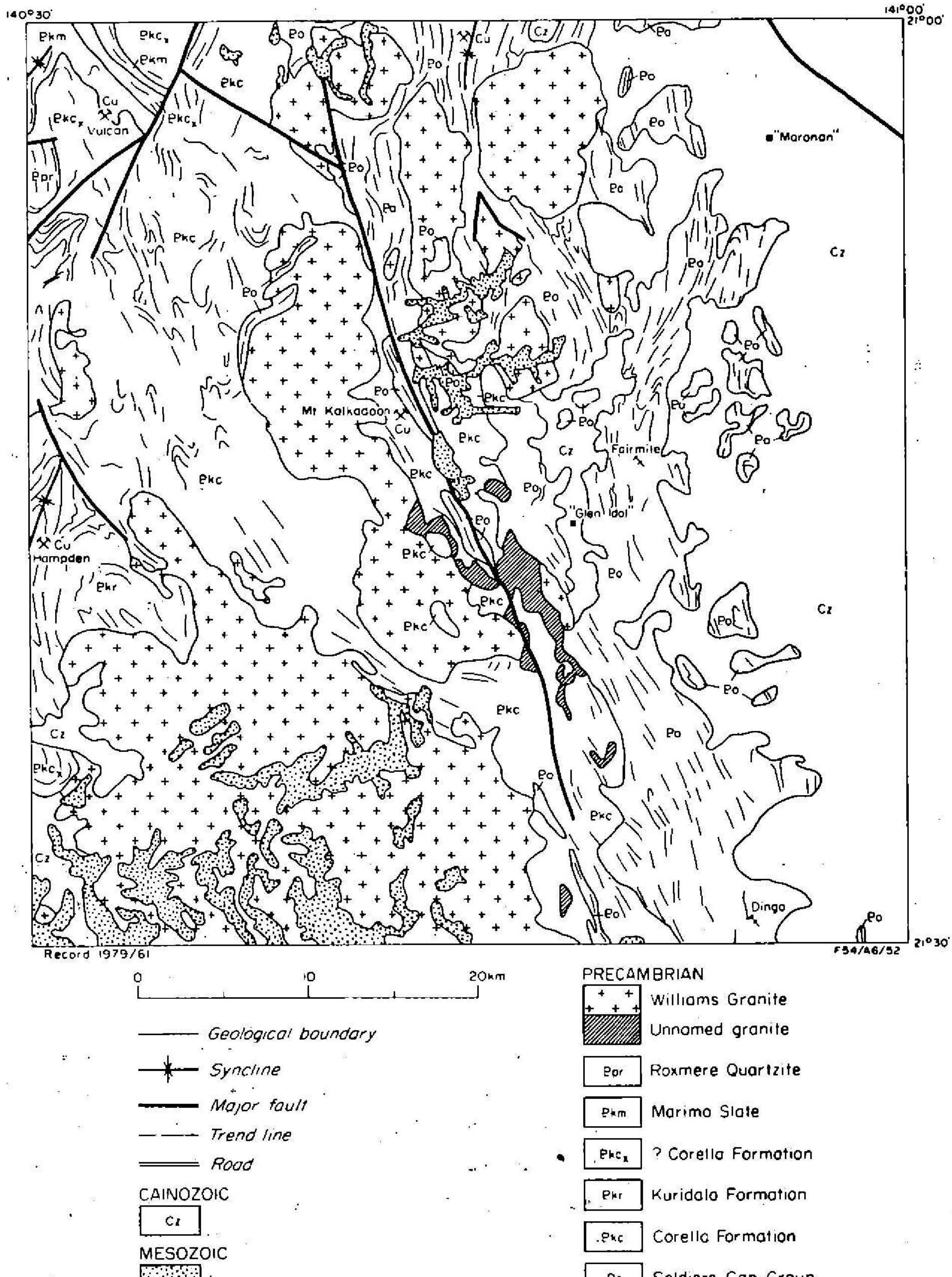


Fig. M9 Geology of the Mount Angelay 1:100 000 Sheet area

east but appear conformable with this unit to the west. The mica schist commonly contains porphyroblasts of garnet+andalusite±staurolite. On the western edge of the sheet area the Kuridala Formation forms an elongate northerly-trending structural basin, outlined by basic sills, which was formed during a second phase of major folding.

Several granitic to locally dioritic intrusions mapped as Williams Granite intrude the Corella Formation, Kuridala Formation, and the Soldiers Cap Group. Numerous fine-grained leucocratic phases of unnamed granite form smaller bodies, mainly in the contact zone between the Corella Formation and Soldier Cap Group.

All formations except the Roxmere Quartzite are intruded by basic plugs, dykes, and sills of several ages. The youngest basic intrusives are easterly-trending dolerite dykes cutting the Kuridala and Corella Formations and the Williams Granite.

Within the Soldiers Cap Group, banded ironstones locally containing Pb-Zn mineralisation crop out discontinuously from the Fairmile prospect in the north to the Dingo prospect in the south. Black slate present in places within the Corella Formation locally contains copper and minor molybdenum mineralisation. Copper mineralisation also occurs in faulted calc-silicate rocks at Mount Kalkadoon. Some gold has been obtained from Pkc_x breccia and associated black slate. Low-grade copper mineralisation localised along shears in Marimo Slate occurs at the Vulcan mine and at a few small prospects nearby. The main copper mineralisation in the area, though, occurs along a north-trending fault within the Kuridala Formation at the Hampden group of mines.

MICROPROBE STUDY OF DUCHESS METAMORPHICS by A.I. Jaques

The rocks examined to date are from SELWYN, MOUNT MERLIN, and MOUNT ANGELAY, and belong to the amphibolite grade of regional metamorphism. Ortho-amphibolites contain amphibole, which ranges in composition from magnesio-hornblende and ferro-hornblende to tschermakitic and edenitic hornblende, and coexisting calcic oligoclase and ilmenite. Para-amphibolites commonly contain calcic plagioclase, pargasitic to edenitic hornblende, salitic pyroxene, ilmenite, and, in some cases, andradite-grossular garnet. Calc-silicate rocks commonly contain quartz, albite, pleochroic chlorine-rich alkali amphibole, salitic clinopyroxene, apatite, and sphene; some samples also contain andradite-grossular garnet. Further work is planned, to determine the effect of bulk composition on the composition of coexisting phases, and the pressure-temperature dependence of mineral assemblages.

MOUNT ISA AND DUCHESS PROJECTS: JOINT INSPECTION OF THE MOUNT ISA/DUCHESS REGION JULY-AUGUST 1979

by

D.H. Blake & G.M. Derrick

PARTICIPANTS: D.H. Blake, R.J. Bultitude, E.K. Carter, G.M. Derrick, R.W. Page, I.P. Sweet, K.R. Walker, P.J.T. Donchak (GSQ), I.J. Hutton (GSQ), W.G. Whitaker (GSQ), I.H. Wilson (GSQ)

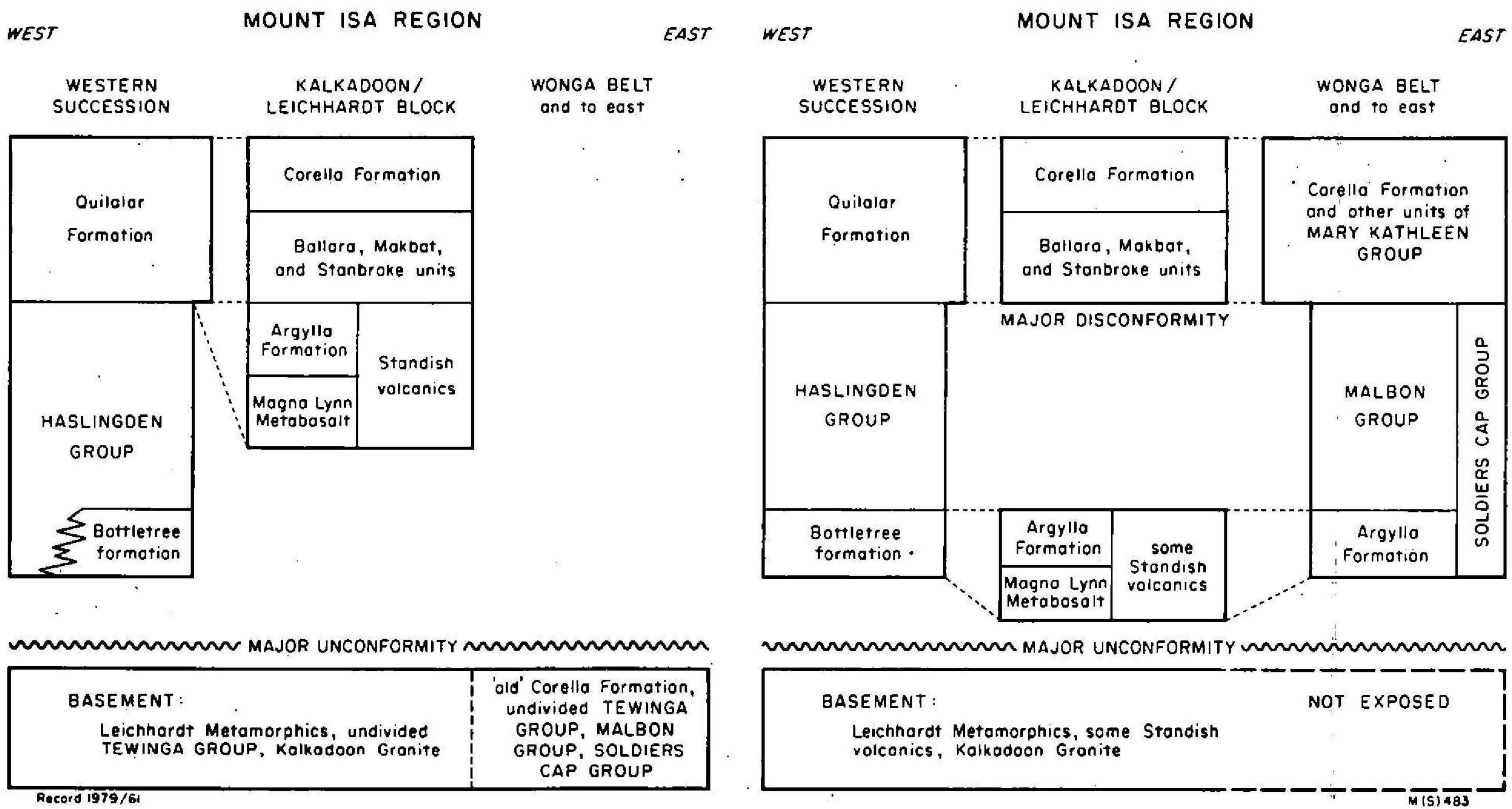
AIMS: The field party examined critical relationships in the Mount Isa/Duchess area in an attempt to resolve some of the differences in interpretation of the regional geology and to select and collect samples for U-Pb zircon geochronology to provide some age constraints. Two main interpretations are currently under consideration, one proposed by Derrick and the other by Blake.

Stratigraphic, tectonic, and locality names mentioned below are as used in recent BMR Records and publications, including 1:100 000-scale geological maps.

RESULTS AND CONCLUSIONS (Fig. M10)

(1) West of the Wonga Belt, in the Kalkadoon/Leichhardt and Blockade Blocks, a major time break separates acid volcanics of the Leichhardt Metamorphics from overlying Magna Lynn Metabasalt: although contacts appear concordant, polymictic conglomerate is commonly present at or near the base of the Magna Lynn Metabasalt, and most of the basic dykes cutting the Leichhardt Metamorphics do not penetrate overlying units.

(2) Basic volcanism resulting in the Magna Lynn Metabasalt and the acid volcanism of the overlying Argylla Formation were not separated by a significant time break: in places the two types of volcanism overlapped, as basic and acid volcanics are commonly interlayered at contacts between the two units. Hence the Magna Lynn Metabasalt and Argylla Formation are closely comparable in age



(a) *Correlations according to Blake*

(b) *Correlations according to Derrick*

Fig. M10 Contrasting corelation schemes in the Mount Isa region and both are significantly younger than the Leichhardt Metamorphics. This conclusion from field evidence is supported by the zircon geochronology of R.W. Page; acid volcanics of the Leichhardt Metamorphics give U-Pb zircon ages of 1865 ± 3 m.y., and those of the Argylla Formation give U-Pb zircon ages of 1777 ± 7 m.y.

(3) A regional difference in magnetic properties was observed between acid volcanics of the Leichhardt Metamorphics, which are generally weakly magnetic or non-magnetic in hand-specimen, and those of the Argylla Formation, which are typically strongly magnetic. Some sediments of the overlying Ballara Quartzite and Corella Formation are also magnetic.

(4) The Bottletree formation, at the base of the Haslingden Group in DUCHESS, unconformably overlies gneissose granodiorite, aplite, dacitic gneiss, and metavolcanics. It consists mainly of metabasalt, metarhyodacite (magnetic), and interbedded conglomeratic sediments. Derrick considers that the volcanics of the Bottletree formation are correlatives of the Magna Lynn Metabasalt and Argylla Formation of the Kalkadoon/Leichhardt Block. Blake, however, regards the Bottletree formation as a basal unit of the Haslingden Group, and considers it to be much older than the Magna Lynn Metabasalt and Argylla Formation.

(5) The Argylla Formation is not separated from the overlying Ballara Quartzite by an angular unconformity. However, the contact between them is thought by Derrick to be a major disconformity. At several localities along the eastern edge of the Kalkadoon/Leichhardt Block massive acid volcanics are in contact with massive and cross-bedded arkose, lenses of conglomerate, boulder beds, and, less commonly, thin-bedded sandstone and calcareous siltstone and arkose, all mapped as Ballara Quartzite. These sediments are interpreted as pediment, alluvial fan, and beach deposits derived mainly from the Argylla Formation. The long time-break between the Argylla Formation and Ballara Quartzite postulated by Derrick, and considered by him to represent the time of deposition of the Haslingden and Malbon Groups elsewhere, is disputed by Blake, who considers that concordancy of bedding and occurrences of acid volcanics, volcaniclastic sediments, and quartzite in both formations indicates general contemporaneity.

(6) The Ballara Quartzite is overlain conformably by calcareous sediments mapped as Corella Formation. These two units are considered to be correlatives of arenites, siltstones, and carbonates of the Quilalar Formation to the west and northwest. Similar rocks mapped as Makbat Sandstone and Stanbroke beds in

DUCHESS and DAJARRA to the south are also probably correlatives of the Quilalar Formation. The Quilalar Formation rests unconformably on Leichhardt Metamorphics and Kalkadoon Granite and conformably on the Haslingden Group. The fact that essentially one quartzite unit, variously named Ballara, Quilalar, Makbat, and Stanbroke, rests on several different units is interpreted by Derrick as evidence of a regional unconformity immediately below the quartzite. Blake, however, considers that the regional unconformity lies below the Magna Lynn Metabasalt and Argylla Formation where these two units are present.

(7) The sequence Leichhardt Metamorphics, Magna Lynn Metabasalt, Argylla Formation, Ballara Quartzite, and Corella Formation ranges from lower greenschist to middle amphibolite grade of regional metamorphism. The Quilalar Formation is essentially unmetamorphosed except in the aureole of the Weberra Granite to the northwest, where middle-greenschist-facies rocks, similar to some Corella Formation rocks, are present.

(8) Calcareous sedimentary rocks mapped as Corella Formation west of the Wonga Belt are regarded by Derrick and others as lateral equivalents of the extensive calc-silicate rocks within the Wonga Belt and to the east. A thin band of quartzite, together with overlying calc-silicate rocks, mapped as Ballara Quartzite and Corella Formation, can be traced almost continuously around the nose of the anticlinal Wonga Belt south of Mary Kathleen, and provides a link between the western and eastern areas of Corella Formation. The two Corella sequences are also considered coeval because they overlie acid volcanics mapped as Argylla Formation both west of the Wonga Belt and to the east (as in the Duck Creek Anticline area). However, Blake considers it highly unlikely that the western and eastern sequences are both Corella Formation. This is because of the abrupt change from 'layer-cake' stratigraphy west of the Wonga Belt to complex stratigraphic interrelationships to the east, the presence of acid and basic volcanics and a greater variety of metasedimentary rocks in the 'eastern' Corella Formation, and the generally much more metamorphosed and deformed nature of the 'eastern' Corella Formation. Blake postulates that the Corella Formation and associated units in the Wonga Belt and to the east were metamorphosed and deformed before, as well as after, the 'western' Corella Formation was deposited; i.e., are part of the basement underlying Magna Lynn Metabasalt and the Haslingden Group (Fig. M10). Derrick considers the generally higher metamorphic grade of the eastern Corella Formation reflects greater volumes of igneous intrusion there, rather than greater age.

(9) A unit of mainly non-magnetic felsitic acid porphyries, the Standish volcanics, are widespread in DUCHESS and DAJARRA, where they are overlain by Makbat Sandstone and Stanbroke Beds. They are regarded by Blake as more or less equivalent to the Argylla Formation, but are considered by Derrick to also include some correlatives of the Leichhardt Metamorphics.

(10) The Standish volcanics are intruded by Wills Creek-type leucogranite, which has now been found to extend along the general line of Wills Creek from near latitude 21°S to latitude 22°S. This granite resembles leucocratic granite mapped as a younger phase of the Kalkadoon Granite (Pgk_2) in MARY KATHLEEN to the north.

(11) Gneissic acid rocks in DUCHESS and DAJARRA, mapped as undivided Tewinga Group by Blake, Bultitude, & Donchak, and regarded by them as mainly acid volcanics which were metamorphosed before the Standish volcanics were laid down, are regarded by Derrick as metamorphosed equivalents of Standish volcanics and Kalkadoon Granite. Derrick considers that the coarse to medium-grained augen gneisses here, as in the Wonga Belt to the north, were derived by deformation of porphyritic igneous protoliths, including granite and high-level dykes, sills, or flows, whereas more even-grained gneisses were derived from even-grained, probably volcanic protoliths. Blake and others suggest that the augen gneisses are products of widespread porphyroblastic growth from mainly volcanic protoliths, and that the variable augen growth and compositional banding within the gneisses reflect lithologic variations within a volcanic pile. In contrast, Derrick believes that much of the compositional banding in the gneiss belts results from extreme deformation of granite and aplite veins intruding volcanic rocks.

(12) In the east, near Cloncurry, no conclusive evidence was found to indicate the presence of an angular unconformity between the Soldiers Cap Group and Corella Formation, nor to definitely confirm the Corella Formation as the younger unit. This is despite contacts which in places trend at right-angles to each other. Calc-silicate breccia commonly present at the contact between the two units, and mapped as part of the Corella Formation, is probably tectonic, and at several localities appears to have been injected or intruded into its present position. Some workers have interpreted the calc-silicate breccias as sedimentary slump deposits formed on a carbonate bank or slope. Where breccia is not present at contacts between the Soldiers Cap Group and Corella Formation, bedding in the two units is concordant. Both units contain

mica schist and banded calc-silicate granofels, and they appear to have had similar deformational histories. From the evidence here, and to the south, Blake and Donchak conclude that the two units are probably conformable and partly lateral equivalents, whereas Derrick suggests that as Corella Formation breccia is in contact with at least three subunits of the Soldiers Cap Group, it probably overlies the Soldiers Cap Group with an onlapping, low-angle, regional unconformity.

The most strongly discordant contacts between Corella Formation and Soldiers Cap Group (e.g. east and southeast of Cloncurry) appear to be confined to areas of west or northwest-trending cross-folds, and are probably structural rather than depositional features.

(13) In order to provide age constraints to various interpretations, the following samples were collected for U-Pb zircon geochronology: Kalkadoon Granite underlying Haslingden Group in the southwest; metadacite lava of the Bottletree formation; granites of the Wonga Belt; acid gneisses mapped as undivided Tewinga Group; quartz-feldspar porphyries mapped as Standish volcanics and Leichhardt Metamorphics, and as Argylla Formation in the Duck Creek anticline and west of Selwyn; Wills Creek Granite; Williams Granite south of Selwyn; and acid volcanics within the Corella Formation east of the Wonga Belt.

GEORGETOWN PROJECT

by

J.H.C. Bain, B.S. Oversby, D.E. Mackenzie, I.W. Withnall,
R.I. McLeod, J.J. Draper & P.A. Scott

STAFF: J.H.C. Bain[1], (Project Leader), B.S. Oversby[1], D.E. Mackenzie[1], I.W. Withnall[1], Geological Survey of Queensland (GSQ), R.I. McLeod[1] (GSQ)*, J.J. Draper[1] (GSQ)*, P.A. Scott[2]*, L.P. Black[3]*, D. Green[4], Geophysicists W. Anfiloff, M. Idnurm, and J.W. Giddings worked with the party part-time

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

*Part time

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

PROGRESS: Field research in the central part of the Georgetown Inlier (FORSAYTH, GEORGETOWN, GILBERTON, NORTH HEAD, FOREST HOME 1:100 000 Sheet areas and small parts of adjacent Sheet areas) has now been completed. An overall account of the results of work done since the projects inception to the end of 1979 will be prepared in 1980 and issued, together with a special map of the region at 1:250 000 scale, as a BMR Bulletin. Field research in adjacent areas of the Georgetown Inlier has begun and will continue for at least three years. This work comprises: 1) reconnaissance geological and geochemical surveys of the Croydon Volcanics and Esmeralda Granite in the west and 2) detailed geological, mineralogical, geochemical, and structural studies to determine the relationships between base metal deposits and stratigraphy in the Einasleigh Metamorphics (mostly east of 144°E) to provide a framework for assessing the base metal potential of the Einasleigh Metamorphics.

FIELD ACTIVITIES: In April Bain, Oversby, Mackenzie, and Withnall spent nine days in the Broken Hill/Olary region of NSW/SA examining aspects of the regional geology and mineralisation for comparison with the geology and mineral deposits of the Einasleigh Metamorphics; and studying NSW and SA Geological Survey approaches to mapping complex high-grade metamorphic terrain. This work was preparation for programmed field research on the Einasleigh Metamorphics.

During July, Mackenzie and Mcleod made a brief reconnaissance of the Croydon region in preparation for fieldwork there in 1980, and Withnall & Draper investigated depositional environments of the Etheridge Group south and west of Georgetown. Withnall also visited the Mount Johnstone area to check geochemical Pb-Zn anomalies, and together with Oversby commenced a stratigraphic structural study of the Einasleigh Metamorphics. Mcleod and Oversby examined a representative selection of rock types and relationships in the western part of the Bagstowe Ring-Dyke Structure, preparatory to Mcleod's study of the eastern part of the structure. Oversby also studied in detail some well stratified 'volcaniclastic sedimentary rocks' on the eastern side of the main Newcastle Range, and examined new stratigraphy and structure and checked some previous work in the Newcastle Range Volcanics. Withnall and the Chief Ranger of the Queensland Department of Aboriginal & Islander Advancement's Archaeological Branch inspected aboriginal sites in the Georgetown, North Head-Forest Home, and Gilberton areas, and Withnall and Oversby visited prospecting operations in the Balcooma (Carpentaria Exploration) and Bundock Basin (Minatome-Urangesellschaft) areas. Withnall examined Proterozoic rocks north of Georgetown with Minatome geologists, and inspected the Digger Creek Granite with ANU Ph.D. student R. Holmes.

Croydon reconnaissance (DEM, RLM)

Reconnaissance in 1979 indicated that a helicopter will be needed to support geological and geochemical survey work in the Gregory Range in 1980.

Much of the Gregory Range-Croydon area is underlain by extensive sheets of apparently homogeneous recrystallised welded rhyolitic ignimbrite generally containing graphite pellets. The ignimbrite is intruded by several varieties of biotite granite and granodiorite(?), the most abundant being the extremely coarse-grained grey Esmeralda Granite. Complex geology is present along the eastern side of the Gregory Range, in the middle Little River-Mount Little area, the Croydon-Tabletop area, and between 'Esmeralda' homestead and 'Glenora' homestead ruins. The first two areas contain agate-bearing basic lavas intercalated with dacite, and rhyolitic ignimbrite, tuff, and spectacularly flow-banded lava. The granite and volcanics in the Croydon area contain numerous quartz reefs, many of which have been mined for gold; at least one company is actively exploring the field for gold and has reported encouraging results from the Tabletop area. To the south, around Stanhills and Mount Cassiterite, and also near 'Alehvale' homestead, tin deposits are associated with linear greisen zones, and, commonly, mafic rocks (possibly dykes) in the Esmeralda Granite; many of these zones, apparently unexploited, are clearly visible on the air-photos. The potential for uranium in the area is not known; however, the Esmeralda Granite has an above average uranium content, the mean value being about 9 ppm.

Depositional environment of the Etheridge Group (IWW, JJD, DEM)

All sediments in the Etheridge Group, Malacura Sandstone, and Yarman Formation (with the possible exception of the upper Robertson River Formation) were deposited in shallow, mainly subtidal water (Fig. M11); gypsum moulds at two levels within the Candlow Formation indicate intervals of intertidal to supratidal environment during its deposition. The abundance of soft-sediment deformation structures in the Etheridge Group indicates that in general sedimentation was rapid. Laboratory analysis of the data collected during this field study is in progress. Most of the subdivisions recognised in the low-grade (phyllite phase) of the Robertson River Formation can also be recognised in the higher-grade rocks (schist phase of the Robertson River Formation) in the Bull Creek area on Robin Hood Station. However, more detailed work would be needed to delineate these units throughout the 'schist phase'. In the Bull Creek area, amygdales, possible metamorphosed hyaloclastites, and vague outlines of lava pillows were observed in fine-grained amphibolites, providing evidence that at least some of the amphibolites and metadolerite 'sills' in the Robertson River Formation are related to the Dead Horse Metabasalt Member.

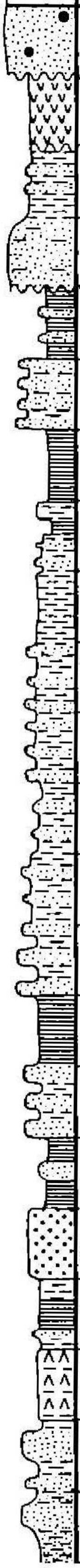
A suspected occurrence of ignimbrite in the Heliman Formation in the Pinnacle Waterhole area was checked but no unequivocal ignimbrite was found. Petrographic examination showed the suspected 'ignimbrite' to be a silty sandstone with flattened clay-rich wisps and lenticles.

<u>Mount Johnstone geochemical anomaly</u> (IWW)

The Pb-Zn soil geochemical anomaly in the Mount Johnstone area reported by Rossiter (<u>Qld Govt Mining Journal</u> 79, 209-212, 1978) coincides with an area of cross-cutting quartz veins containing gossanous galena boxworks. Nearby, the Townley Formation contains limonite pseudomorphs after pyrite, similar to those found elsewhere in the Townley Formation in association with anomalous levels of zinc.

<u>Stratigraphy of the Einasleigh Metamorphics</u> (BSO, IWW)

The high-grade (middle amphibolite to granulite facies) Einasleigh Metamorphics are widespread in the central Georgetown Inlier; they contain apparently stratiform base-metal sulphide deposits at a number of localities, including a previously important one at Einasleigh. Systematic semi-detailed studies of the unit have been made in GEORGETOWN, FORSAYTH, and GILBERTON, in an attempt to delineate its stratigraphy, so that potentially mineral-rich



Stratigraphic Unit \ Sedimentary Feature	Lamination	Sm-m scale trough x-stratification	Planar cross stratification	Scour & fill	Bedding: Flaser	Bedding: Wavy	Bedding: Lenticular	Clay drapes	Asymmetric ripplemarks	Climbing ripples	Wrinkled surface	Flute marks	Other current lineation	Sandstone dykes	Load casts	Contorted stratification	Mudclasts	Erosive-discordant bases	Siliceous siltstone	Concretions	Gypsum molds	INTERPRETED ENVIRONMENT
INORUNIE SANDSTONE	P	C	C						P								P					FLUVIATILE
CROYDON VOLCANICS	*rhyolitic ignimbrite; rhyolite, dacite; basaltic andesite and/or basalt*																					CONTINENTAL IGNIMBRITE
YARMAN FORMATION	C	C							P			P	P			R						TURBIDITE (PRODELTAIC)
MALACURA SANDSTONE	P-C	P				R	R		P				P		P		C			R		FLUVIATILE TO DELTAIC
LANGDON R SILTSTONE	C	R				R	R								R	P						SUBTIDAL
UPPER CANDLOW FORMATION	C						R										C		R	P	R	INTERTIDAL -SUBTIDAL
Stockyard Cr Siltstone Member																						SUBTIDAL
MIDDLE CANDLOW FORMATION	C					R	R							R		C	C-R					SUBTIDAL
White Bull Member	P															P	P		C			SUBTIDAL
LOWER CANDLOW FORMATION	C	P	P				R									P	C		R	P	P	INTERTIDAL - SUBTIDAL
HELIMAN FORMATION U	C	R												P	P	C	C		C			SUBTIDAL
HELIMAN FORMATION M	C															P			R			SUBTIDAL
HELIMAN FORMATION L	C														P	C	C		C			SUBTIDAL
TOWNLEY FORMATION U	C	R												P		C	P		R			SUBTIDAL
TOWNLEY FORMATION M	P																					SUBTIDAL
TOWNLEY FORMATION L	P															C	P			R		SUBTIDAL
UPPER ROBERTSON R FORMATION	C	R												P		C	P		R			DEEP SUBTIDAL
Tin Hill Quartzite Member	R																					? Chemical sediment
MIDDLE ROBERTSON R FORMATION	C-R													R		P						SUBTIDAL
Dead Horse Metabasalt Member	*hyaloclastite; pillows; amygdales; interbedded sediments & siliceous rock*																					SUBMARINE BASALT
LOWER ROBERTSON R FORMATION	P	P	R	C		R	R		R	P				P	P	R	P	P		C		? SANDY DELTA
BERNECKER CREEK FORMATION	C	C	R		P	P	P	P	P	R	P	P	P	P	P	P	P	?R				WAVE-DOMINATED SHORELINE

Legend: Conglomerate; Sandstone; Siltstone - non carbonaceous mudstone; Carbonaceous mudstone; Basalt; Quartzite; Acid volcanics

R - *Rare* **C** - *Common* **P** - *Present*

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Fig. MII Summary of sedimentary features, Middle Proterozoic rocks, Georgetown Inlier intervals of the unit can be correlated from one area to another, and relations between the Einasleigh Metamorphics and similar high-grade rocks in the Lolworth-Ravenswood Block farther south can be better understood.

South of 'Lyndhurst', the preserved Einasleigh Metamorphics probably form the overturned eastern limb of a large, north-plunging second(?)-generation antiform. The metamorphic sequence consists mainly of various proportions of resistant, well-exposed, leucocratic quartzofeldspathic gneiss, and leucocratic to mesocratic calc-silicate (hornblende and/or diopside) gneiss; less resistant, mostly poorly-exposed, melanocratic biotite-rich gneiss and schist occur sporadically throughout. The quartzofeldspathic and calc-silicate gneisses are commonly laminated to thinly-banded; these laminae and bands are believed to represent original sedimentary stratification. Magnetite is common locally; its occurrence appears to be stratigraphically controlled, all rock types in certain intervals being magnetite-rich (or alternatively, magnetite-free). In general terms, the sequence is, from east to west -

(1) magnetite-free biotite gneiss and schist with subordinate leucocratic calc-silicate gneiss;
(2) magnetite-rich leucocratic quartzofeldspathic gneiss with biotite gneiss and schist;
(3) magnetite-rich leucocratic quartzofeldspathic gneiss and mesocratic calc-silicate gneiss with biotite gneiss and schist;
(4) magnetite-rich mesocratic calc-silicate gneiss with subordinate leucocratic quartzofeldspathic gneiss;
(5) magnetite-free mesocratic calc-silicate gneiss with biotite gneiss and schist.

The sequence is bounded to the east by Dido Granodiorite, and in the west by Dumbano Granite. Some probable cross-laminae occur, but these give contradictory facing data, presumably because of folding. Consequently, the true stratigraphic order of units 1 to 5 is not yet known.

The Einasleigh Metamorphics in the 'Oak-Park' area are similar in part to those described above, but they cannot be correlated directly. In addition, the 'Oak Park' area is structurally quite complex, and neither the structure nor the detailed stratigraphy are yet fully understood. A notable feature of the Einasleigh Metamorphics in this area is the occurrence of apparently stratiform massive pyritic and barite-rich bodies at one or more levels within the unit.

The Bagstowe Ring-Dyke Structure (RIM, BSO)

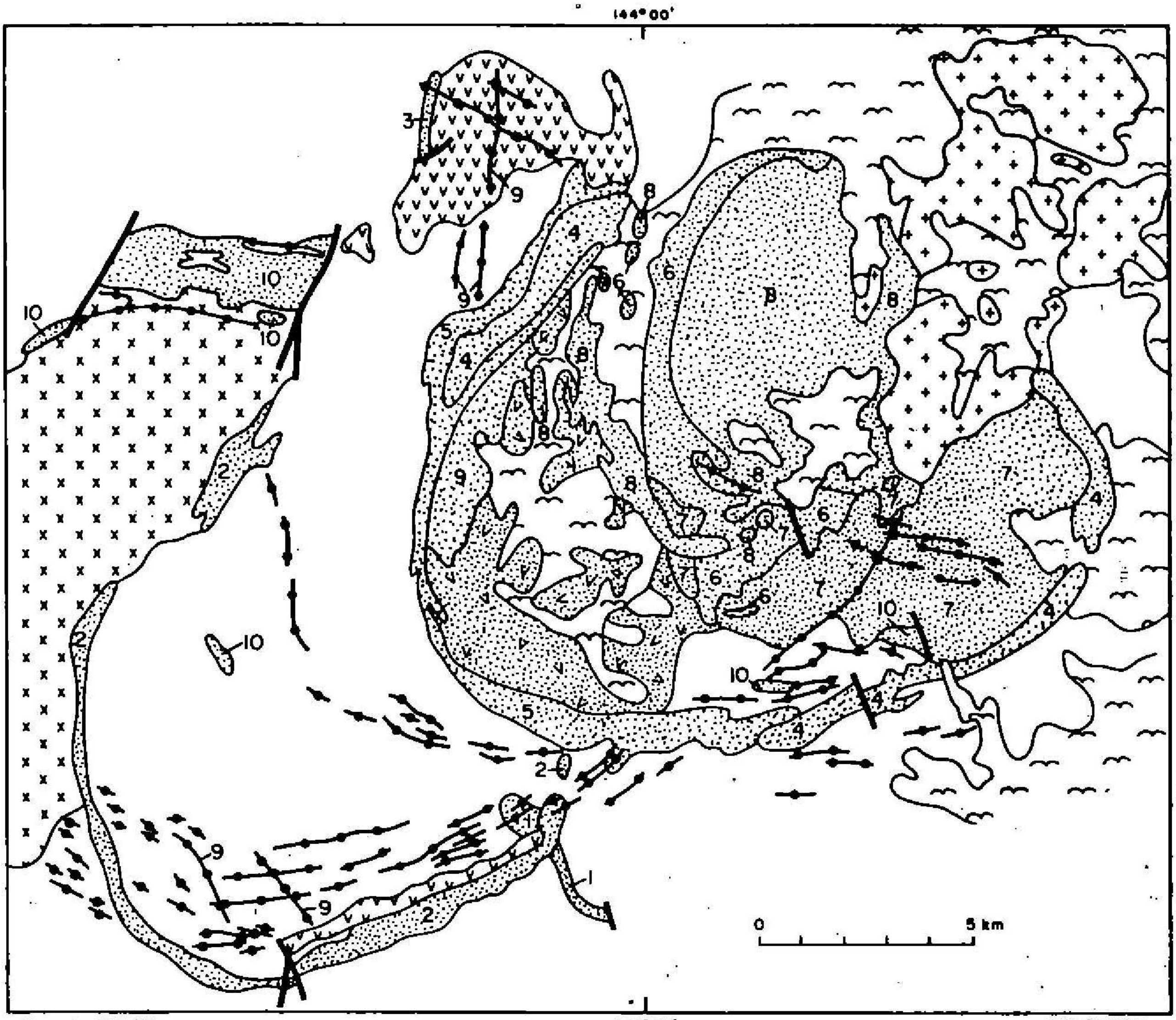
The Bagstowe Ring-Dyke Structure 'Complex' occurs in east-central GILBERTON and west-central LYNDHURST. It consists of a suite of high-level intrusive and subordinate extrusive rocks of late Palaeozoic age, and probably formed as a result of large-scale subsidence with concomitant major ignimbrite eruptions. The structure is of a type which presumably occurs locally beneath, and in the lower parts of, ignimbrite-dominated sequences like the Newcastle Range Volcanics farther north; its study is designed to enhance understanding of the interplay between late Palaeozoic volcanism and plutonism, and the controls of related mineralisation in the region.

The Bagstowe structure was originally studied comprehensively by Branch (BMR Bull. 76, 1966). Some results of this later work are as follows:

(1) A previously unrecognised coarse equigranular to porphyritic biotite granite of Elizabeth Creek type occurs in the northeast (Fig. M12). It was originally included in the Four Mile Creek and Northeast Stocks (Fig. M12, units 7 and 8 respectively), both of which apparently postdate it. The rock is slightly different from Lochaber Granite in the latter's type area to the north-east, but relationships between the two are not yet known. It may be that the Elizabeth Creek-type granite does not belong to the ring-dyke structure proper but to a somewhat earlier phase of late Palaeozoic plutonism (cf. Claret Creek Ring-Dyke Structure). In this respect, it is comparable to the Carboniferous (?) Culba Granodiorite to the west.

(2) Hornblende-biotite microdiorite and diorite (Fig. M12, unit 6) are more extensive to the west and south of the Northeast Stock than indicated by earlier work. They are probably older than the Four Mile Creek Stock and Northeast Stock/Central Ring Dyke, although some relationships suggest simultaneous emplacement of mafic and felsic magmas. The Central Ring Dyke is quite irregular in plan; numerous small bodies of biotite microgranite between it and the Northeast Stock suggest that the two bodies are connected at shallow depth (or were once connected not far above the present level of exposure). However, there is no direct connection at the surface, as indicated by Branch (1966, Plate 42).

(3) The East-West Ring Dyke (Fig. M12, unit 4) is less extensive than originally thought. It is probably younger than the Pink Ring Dykes (Fig. M12,



Record 1979/61 E54/A16/19

Mesozoic and Cainozoic rocks, including alluvium

Carboniferous-Permian (?) Bagstowe Ring-Dyke Structure:

- *Extrusive rhyolitic to dacitic(?) lava and ignimbrite; extrusive and minor intrusive breccia*
- *Intrusive and extrusive(?) rhyolitic ignimbrite; minor intrusive breccia (Grey Ring-Dykes)*
- *Intrusive rocks: 1 - porphyritic rhyolite/microgranite (Castle Hill Dyke); 2 - porphyritic biotite - hornblende microgranodiorite (Mount Rous Ring-Dyke); 3 - porphyritic hornblende microgranite; 4 - hornblende - biotite microgranite (East-West Dyke); 5 - porphyritic rhyolite/microgranite (Pink Ring-Dykes); 6 - hornblende - biotite microdiorite; 7 - hornblende-biotite microgranodiorite (Four Mile Creek Stock); 8 - biotite microgranite (Northeast Stock and Central Ring-Dyke); 9 - porphyritic augite-hornblende - quartz andesite; 10 - aphyric and porphyritic rhyolite dykes and "cone sheets" (all dykes shown are of this lithology unless indicated otherwise)*

Carboniferous (?):

- *Coarse-grained equigranular to porphyritic biotite granite*
- *Medium-grained equigranular hornblende-biotite granodiorite (Culba Granodiorite)*

Proterozoic metamorphic rocks; Proterozoic and Siluro-Devonian (?) intrusive rocks

Fig. M12 Geological map of the Bagstowe Ring-Dyke Structure, Georgetown Inlier

unit 5), and may be younger than the Four Mile Creek Stock. There is apparently no contact between it and the Northeast Stock/Central Ring Dyke preserved at the present level of exposure; age relationships between it and those two bodies are consequently not definitely known.

(4) The seven more-or-less distinct Grey Ring Dykes separated by steeply dipping arcuate screens of country rock described by Branch (1966) have not been recognised as such in recent work. Some definite ignimbrite dykes do occur in the outcrop area of postulated Grey Ring Dykes, but those observed are relatively small structures. The occurrence of at least one apparently near-horizontal contact between country rocks and overlying grey rhyolitic ignimbrite suggests that some, and perhaps most, of the ignimbrite is extrusive. The Grey Ring Dykes may actually be disrupted and locally rotated segments of one or more extrusive ignimbrite sheets belonging to a subsided volcanic edifice. Data are not adequate to resolve this problem unambiguously, however.

(5) Microgranodiorite of Mount Rous Ring Dyke type (Fig. M12, unit 2) is probably older than the Pink Ring Dykes (Fig. M12, unit 5), but it apparently does not occur in the outcrop area of the postulated Grey Ring Dykes.

(6) Shallowly inward-dipping rhyolite 'cone-sheets' (Fig. M12, unit 10) are probably less abundant than originally suggested, although locally they are common; all are apparently relatively young. Their significance and mode of formation are not clear at present.

(7) The 'volcanic neck' originally recognised in the northwestern part of the Bagstowe structure (Branch, 1966, Plate 42) consists of a nearly flat-lying stratigraphic sequence of rhyolitic to dacitic(?) lavas and ignimbrites, ignimbritic and air-fall(?) breccias and local extremely coarse epiclastic conglomerate cut by high-angle andesite and rhyolite dykes. The sequence may overlie a vent area, but it is probably not a vent filling as such, at the present level of exposure. There are no indications of mineralisation.

The Bagstowe Ring-Dyke Structure represents a localised complex centre of late Palaeozoic igneous activity. Although the igneous activity was probably long-lived, and although no occurrences of mineralisation associated with the complex have so far been found, on theoretical grounds it seems that it should have been an important focus of mineralisation.

OFFICE ACTIVITIES

FOREST HOME-NORTH HEAD REGION (DEM, IWW)

Stratigraphy: As a result of field work during July-August 1978 and subsequent airphoto interpretation, the stratigraphic nomenclature of the mid-Proterozoic Etheridge Group was substantially revised (Fig. M11). The Heliman Formation was divided into three unnamed subunits - two topographically prominent subunits containing many resistant siliceous beds separated by a recessive subunit that contains few siliceous beds. A new unit, the Townley Formation, was recognised below the Heliman Formation. It consists of white to grey, locally carbonaceous fine sericitic or lithic quartz sandstone and siltstone, with minor quartzose siltstone and sandstone. A basal, locally gossanous sequence of white laminated sericitic siltstone and sandstone contains anomalously high levels of Zn. The Robertson River Formation has been divided into two unnamed but mappable subunits: the upper subunit is characterised by carbonaceous siltstone and mudstone, and impure limestone and calcareous siltstone that grade into calc-silicate rocks. The lower, mainly pelitic subunit contains the Tin Hill Quartzite Member and the Dead Horse Metabasalt Member (Fig. M11). It corresponds with the middle and lowermost subdivisions of the Robertson River Formation in Fig. M11, but these subdivisions, though locally recognisable, have not been used in mapping owing to the difficulty in tracing their mutual boundary. Each subunit has schistose and phyllitic phases, depending on metamorphic grade.

Two granodiorite plutons in NORTH HEAD, formerly Forest Home Granodiorite, were found to be sufficiently distinctive to be named separately, viz. Carnes Granodiorite and Gongora Granodiorite.

Petrographic studies and additional airphoto interpretation showed that the stratigraphy of the Maureen, Dismal Creek, and Cumberland Range Volcanics is also more complex than originally thought, and subdivisions were extensively revised. Petrographic studies of the Prestwood Microgranite resulted in part of it (in the Cumberland Range) being recognised as a distinct rock type, the Mount Sircom Microgranodiorite.

Candlow Formation geochemical study: Results of chemical analyses by AMDEL of 179 specimens of the Candlow Formation, mainly from drill core, have been received: the analyses were for Ag, Au, As, Bi, Ba, Y, Zr; Rb and Sr (some); Ca, S, CO_2; Ca, Mg, Fe, Ti, Mn, Na, and K (most); and selected samples for all major elements. Analyses for transition metals are not yet available. Some interesting but preliminary results are high As (up to 2000 ppm) and Au (up to 60 ppb) values in some pyritic samples, and organic carbon contents ranging up to 9.3 percent and commonly over 5 percent. However, the carbonaceous rocks are low in base metals, particularly Zn, compared to 'average black shales'. A petrographic study of the Candlow Formation is also in progress.

Stream-sediment geochemistry (JB, PAS)

Regional stream-sediment geochemical surveys have been carried out in FORSAYTH, GILBERTON and GEORGETOWN (see previous Annual Summaries) to determine regional geochemical patterns and aid assessment of the region's mineral potential. Analytical work and data processing are now complete. A set of 1:100 000 Geochemical Series maps were issued in 1977 for FORSAYTH, and raw data in microfiche form have recently been released for GILBERTON. These data reveal the existence of high background levels of Sn (more than 10 ppm) in more than 300 samples (Fig. M13); 52 of these samples contain more than 50 ppm, with values ranging up to 570 ppm.

The area of high Sn values corresponds closely with the principal outcrop areas of Mesozoic sedimentary rocks. This close spatial relationship suggests that parts of the largely fluviatile and marginal marine Upper Jurassic-lower Cretaceous clastic sedimentary rocks (Eulo Queen Group and Gilbert River Formation) contain similar concentrations of cassiterite as those seen at Tintarple about 100 km to the north-northwest.

This is the first substantial evidence that these Mesozoic formations are widely, if sporadically, mineralised. It may indicate that the northeastern Queensland tinfields are flanked to the west by an extensive halo of second-cycle Mesozoic placers. Some of these may warrant extensive exploration. Additionally, erosion of these mineralised sedimentary rocks may have led to the concentration of cassiterite in Cainozoic alluvials - possibly in economic grades and tonnages. For example, extensive dissected Cainozoic alluvium, along at least 100 km of the Gilbert River downstream from a point about 15 km above its confluence with the Robertson River, may contain cassiterite. In this section the Gilbert River cuts through four substantial topographic barriers each associated with a shallow upstream basin partly filled with Tertiary and

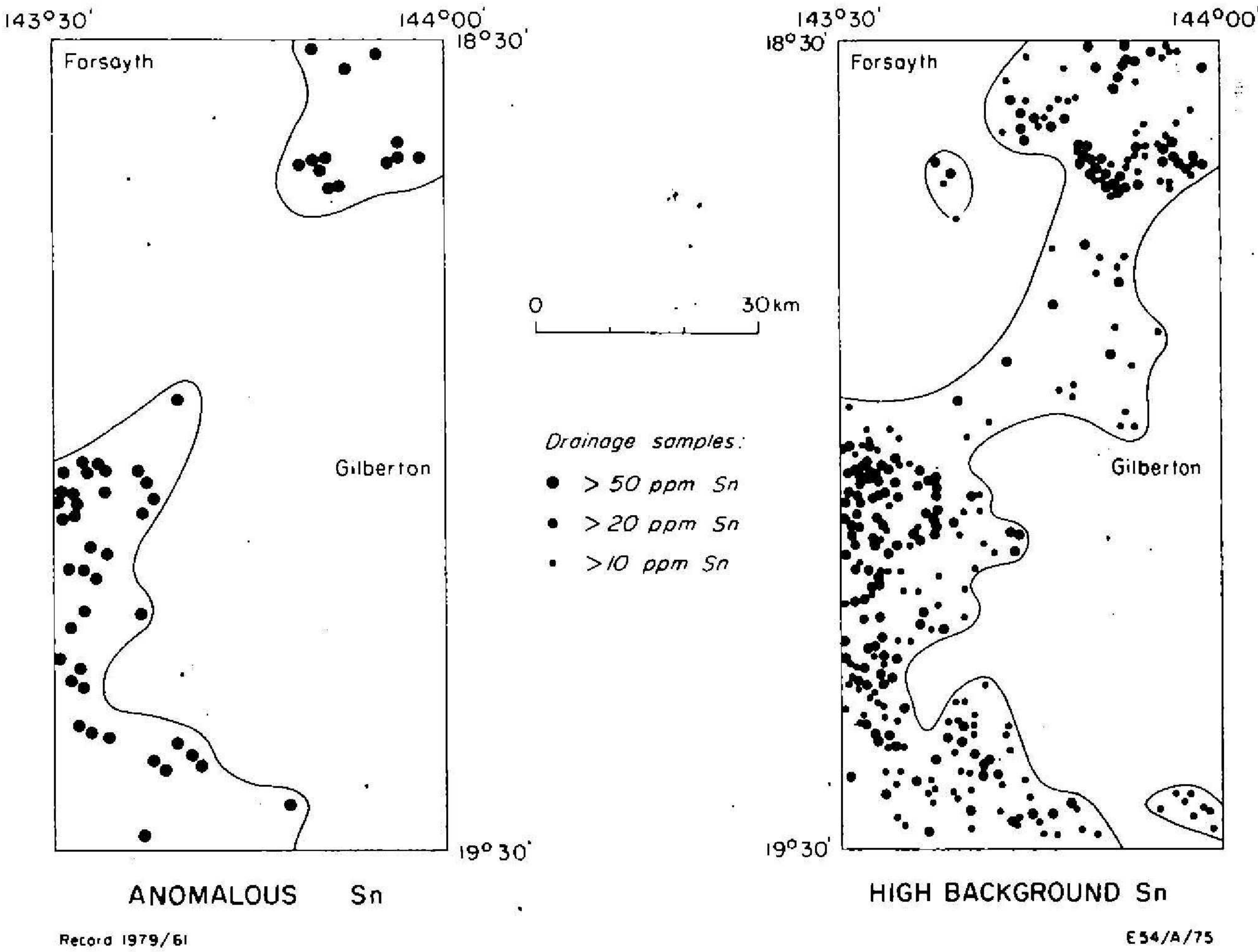


Fig. M13 Distribution of stream sediment samples with anomalous levels of Sn

Quaternary alluvium. The barriers are caused by resistant rock formations that cross the river.

The combination of an extensive, well-mineralised source region, well-defined depositional sites in the form of a series of topographic depressions that probably formed a chain of giant riffles, and a depositional period lasting at least 5 million years, suggests that the Gilbert River alluvials may have potential for large alluvial Sn deposits. Similar attractive, but perhaps less favourable, Quaternary placers may exist elsewhere in the region if the area of mineralised Mesozoic sediments is more extensive than so far demonstrated. Other aspects of the results and progress of the geochemical work in this Project are covered in the Metalliferous Laboratory report.

Geochronology

Work continued on Rb-Sr and U-Pb zircon dating of samples from the central part of the Georgetown Inlier. Results and progress are given in the Metalliferous Laboratory report.

Magnetostratigraphy of the Newcastle Range Volcanics (BSO, MI)

Measurements of samples collected from the main and eastern parts of the range in 1978 in an attempt to correlate sequences of the two areas were completed early in the year. Despite considerable scatter in the remanence directions in some of the units, polarities can be assigned to all of them.

The lowermost epiclastic rocks in both sequences show normal polarity, whereas the overlying ignimbrite-dominated units Cn_2 and Cn_{II} both show an ascending pattern of alternating reverse-normal-reverse polarity. These data suggest that the lower parts of both sequences are time-equivalent; stratigraphic data are consistent with this. Consideration of litho- and magneto-stratigraphic results from higher parts of both sequences suggests that eastern range units Cn_3 to Cn_5 could be represented by a hiatus in the main range sequence, while unit Cn_6 is probably common to both sequences (although magnetic data were only obtained from it in the main range). However, the time-significance of any correlations between the main and eastern range sequences must remain uncertain at best.

The magnetic data from the Newcastle Range Volcanics have also produced a new mid-Carboniferous pole position for Australia, supplementing an earlier, rather poorly-defined, one. Rapid pole movement for the continent during Carboniferous time is confirmed.

Agate Pocket gravity survey (BSO, WA)

A detailed gravity traverse made across the northwestern half of Agate Pocket in 1978 in an effort to define the subsurface structure of the Agate Creek Volcanics has indicated that outcropping basic rocks probably occur in a simple shallow basin, at least in the area traversed. There is no indication of any concealed graben-like structure, nor of substantial basic intrusive bodies. A 20-mGal gravity low in the vicinity of Agate Pocket is attributed to Robin Hood Granodiorite, which underlies most of the Agate Creek Volcanics. The flank of this low coincides with the contact between the granodiorite and low-grade Proterozoic metasedimentary rocks of the Etheridge Group (Robertson River Formation). A subsidiary low, coincident with exposed rhyolitic lavas on the northeastern side of Agate Pocket, suggests that these extrusive rocks are underlain by an intrusive 'root'.

Maps and reports

Preliminary editions of Forest Home Region and North Head Region 1:100 000-scale geological maps were prepared from photographically reduced revised airphoto-scale compilation sheets of FOREST HOME, NORTH HEAD, and parts of GILBERT RIVER, ESMERALDA, and ABINGDON DOWNS, and are being printed. A catalogue of field compilation sheets (reduced to 1:100 000 scale) and companion field observation sheets was issued as Record 1979/12. A data Record describing the geology of GILBERTON was completed and work commenced on a similar Record on the North Head/Forest Home region.

Definitions of sixteen new and five revised sedimentary, metamorphic, and igneous rock units in the North Head/Forest Home region were approved by the Stratigraphic Nomenclature Subcommittee of the Queensland Division of the Geological Society of Australia. Papers detailing sedimentary, metamorphic, and igneous rock unit nomenclature in the Gilberton & North Head/Forest Home areas, and new tin exploration targets indicated by recent BMR geochemical surveys in the Georgetown Inlier were submitted to the Queensland Government Mining Journal for publication.

Bain submitted a dissertation on an aspect of the project work - a detailed study of the Jubilee Plunger gold, silver, and base-metal deposit - to James Cook University in partial fulfillment of the requirements for his successfully achieved degree of Master of Science (Exploration & Mining Geology).

Lectures

Bain, Oversby and Mackenzie prepared talks on aspects of their work and delivered them at the BMR Tuesday Lecture Series. Abstracts were written and Bain and Oversby gave revised versions of their talks to the 8th BMR Symposium.

GEOLOGICAL INVESTIGATIONS IN WESTERN AUSTRALIA

YILGARN PROJECT

by

A.J. Stewart

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

In response to an invitation by the Geological Survey of Western Australia, BMR supplied three geologists to assist in field geological studies of the Sandstone and Youanmi 1:250 000 Sheet areas of the Archaean Yilgarn Block. The two areas were part of a larger project aimed at completing the regional geological survey of Western Australia in 1979 - the 150th anniversary of the State's foundation. Field work commenced in April. The Sandstone Sheet was mapped by S. Williams (GSWA, 14 weeks), Tingey (13 1/2 weeks), Offe (9 weeks). Youanmi was mapped by I. Williams (GSWA, project leader, 15 weeks), Stewart (14 weeks), and M. Elias (GSWA, 9 weeks). Instead of traditional base camps, the party used shearers' quarters and a rented house in the township of Sandstone. The mapping was completed in two-thirds of the time allotted.

The rocks underlying the two Sheet areas are typical of the Archaean, and comprise (1) enclaves of strongly banded gneiss (2) synforms and fault-blocks of greenstone and (3) voluminous granitoids surrounding and intruding the gneisses and greenstones.

The banded gneisses comprise alternating layers of biotite gneiss, granitic gneiss, and tonalitic gneiss, and in many places display a remarkably straight and regular banding (layering). The gneisses also include pods and layers of amphibolite and recrystallised quartz-magnetite ironstone. The gneisses are intruded by numerous masses of strongly foliated but non-layered gneissic granitoid (or orthogneiss), and in many places the gneiss and granitoid are intimately mixed, and form migmatite or agmatite. At one locality, banded gneiss is intruded by dykes of granodiorite which were then tightly folded about axial surfaces parallel to the banding of the host gneiss. The greenstone belts trend generally north, and contain a variety of weakly metamorphosed igneous and sedimentary rocks, of which the most abundant are basalt, dolerite, gabbro (including part of a very large gabbro lopolith about 4000 m thick on the western edge of the Youanmi Sheet area), ultrabasic rocks, and banded iron formation. High-magnesium basalt (komatiite), felsic volcanics, chert, slate, and shale are less common. A conglomerate composed of flat pebbles of chert is an extensive marker horizon in the greenstone belt in the southeast of Youanmi. Fuchsite quartzite crops out at the base of a greenstone belt in the extreme southeast of Youanmi, and dark limestone is interbedded with shaly sediments a few kilometres north of Sandstone township. The greenstone belts are generally synformal, and have steeply dipping axial surfaces and moderately steeply plunging axes. In many places, however, faulting has removed one limb of the synform. Elsewhere again, the margins of the greenstone belts are intruded by massive to weakly foliated granitoid. The granitoids are by far the most abundant rock in the Yilgarn Block, but in general are poorly exposed, or where exposed, are deeply weathered. The most abundant variety is medium to coarse-grained, massive to weakly foliated, biotite granitoid, accompanied by abundant granite pegmatite. Also common are bodies of fine-grained granitoid, whereas coarse porphyritic granitoid is rare. Many of the granitoids are adamellitic in composition; granite is also common, but granodiorite and tonalite are rarely exposed.

Proterozoic rocks in the central Yilgarn area are represented by east-trending unmetamorphosed dolerite dykes.

Perhaps the most significant problem in the Archaean rocks of the Yilgarn Block is to establish whether the banded gneisses are the oldest rocks in the area, and are remnants of an old sialic basement on which the greenstones were deposited (Gee, <u>Tectonophysics</u>, 58, 327-69, 1979), or whether they are much younger gneissic margins around intrusive diapiric granitoids (Glikson, Geol. Soc. Amer. Bull, 83, 3323-44, 1972). Unfortunately, exposures in the Youanmi and Sandstone Sheet areas are too poor to provide convincing field evidence either way on this problem. It can be stated, however, that on the map scale, the banded gneisses show no tendency to crop out around granite bodies, but instead form remnants and rafts enclosed in and intruded by the granites.

VOLCANOLOGY

PAPUA NEW GUINEA VOLCANOLOGY AND TECTONICS

by

R.W. Johnson, D.A. Wallace (part-time), W.D. Palfreyman (part-time), & D.E. Mackenzie (part-time)

FATAL KARKAR ERUPTION OF 8 MARCH, by D.A. Wallace & R.W. Johnson

The work of the Volcanological Sub-section this year was overshadowed by the deaths of R.J.S. Cooke, Senior Government Volcanologist at the Rabaul Volcanological Observatory, who had been on secondment from BMR since 1971, and of E. Ravian, an Observatory Technical Officer.

Cooke and Ravian were killed early in the morning of Thursday 8 March (probably between 0100 and 0230 hours) by a hot, high-velocity, directed blast of gas and ejecta, which originated from a vent on the floor of the inner caldera of Karkar volcano, travelled obliquely for a distance of over 900 m to the rim of the 300 m-high caldera wall, and there enveloped the observation camp. Fifty centimetres of ash and debris, including boulders up to 1 m across, were deposited over the camp area. Disaster was first suspected when Cooke and Ravian failed to keep a scheduled radio contact at 0800 hours on the 8th. An investigating party was sent up from Kinim observation post at the coast, and found the two bodies among the debris at the caldera-rim camp.

A request was received later in March from the Geological Survey of Papua New Guinea (GSPNG) for volcanological assistance on Karkar and in Rabaul. Wallace left Canberra on 30 March on secondment to GSPNG for two months, and assisted Rabaul volcanologists in assessments of the cause and effects of the March eruption, and of the possibility of further outbreaks. Wallace returned to, and Johnson left, Canberra at the end of May.

Johnson's role was to sort out Cook's offices, to retrieve volcanological reports that Cooke had had in preparation, and to take over Cooke's commitment to a GSPNG volcanological memoir that Cooke had hoped to edit. Johnson returned to Canberra on 10 July, following one week of collecting inclusions and lava samples from the 1951 cumulodome of Lamington volcano, and lava samples from the Sogeri Plateau near Port Moresby.

UNFINISHED WORK OF R.J.S. COOKE, by R.W. Johnson

Volcanological papers

The texts of five papers being prepared by Cooke are near completion. These deal with the eruptive history and geology of the following active volcanoes: Pago (1911-33), Ritter, Bam, Ulawun (between 1700 and 1958 only), and Lolobau.

The paper on the 1911-33 activity of Pago is particularly important as this volcano is near a flourishing oil-palm project, and as virtually nothing had previously been reported in the volcanological literature about the early-20th-century activity. Cooke, however, has synthesised a detailed account, mainly from missionary sources, that throws considerable light on the nature of the eruptions. Following is the abstract from his paper.

A major eruption took place between 1911 and 1918 from Pago, the volcano inside Witori caldera. It produced a destructive ashfall, a pumice-and-ash cone, and dacitic lava that may still have been flowing as late as 1923 (but probably not by 1929). The final volume of the flow is about 0.8 km^3, and estimated rates of lava effusion are 2-10 $m^3 s^{-1}$. These rates are high compared to those estimated for modern flows of andesite from Bagana volcano, and may be the reason why Pago is a low-lying shield, rather than a steep-sided cone like Bagana. Increased activity from Pago was noted in the late 1920s and early 1930s, and particularly in 1933 when fine ash was deposited several kilometres from the volcano.

The text of the paper on Bam volcano by Cooke (Johnson is co-author) is complete.

Bam Island is one of the least active of the 10 historically active volcanoes in the Bismarck volcanic arc. It is the andesitic top of a mainly submarine central-type volcano. Minor explosive eruptions from a deep summit crater were recorded between 1954 and 1960, but earlier observers did not report events that can definitely be identified as eruptions, although stories told by the islanders on Bam may refer to them. Lava flows are a main constituent of the island, but none has been produced historically.

GSPNG memoir

Twenty-four papers on Papua New Guinea volcanological topics have been promised by authors at the Rabaul Volcanological Observatory, at BMR, at universities, and privately. Manuscripts are to be submitted by 1 January 1980, and a tentative publication date is late 1980. The five papers by Cooke, listed above, will be included in the memoir, which will be called the 'Cooke-Ravian volume of volcanological papers'. Johnson will be editor.

Research correspondence

Cooke write extensively to institutions and individuals for information on reports of pre-Second World War activity of Papua New Guinea volcanoes. Arrangements have been made with the Pacific Manuscripts Bureau (Australian National University) to microfilm this correspondence for distribution to several major libraries in Australia and Papua New Guinea.

VOLCANOLOGICAL ARCHIVES AND BIBLIOGRAPHY OF REFERENCES TO PRE-1944 VOLCANIC ACTIVITY, by W.D. Palfreyman & R.W. Johnson

A systematic compilation has ben started of references to pre-1944 volcanic activity throughout Papua New Guinea (1943 is the year of the last Rabaul eruption). The starting point of the compilation is the references that Cooke collected (Johnson produced a reference-card index of these while in Rabaul), and additional references are being extracted from personal reference indexes as well as from published compilations of Papua New Guinea earth-science references.

A circular has been distributed to a wide range of institutions and individuals requesting references that they believe would be appropriate for the compilation. Copies of the reference material are being catalogued and filed, and will be added to an archival system of volcanological reports, photographs, field note books, rock slides, and reprints - including, particularly, those of the late G.A.M. Taylor. Submissions to the archival system are invited. Translation of the foreign-language references is being arranged, and translations will be included in the reference catalogue.

NEW BRITAIN ISLAND-ARC AND BACK-ARC PETROLOGY AND TECTONICS, by R.W. Johnson

Witu Islands petrology and geochemistry

A detailed study of rocks from the Witu Islands was completed in collaboration with R.J. Arculus (Research School of Early Sciences, Australian National University - RSES/ANU). It is to be published in a special issue of Bulletin Volcanologique that will contain papers delivered at the International Geodynamics Conference on western Pacific tectonics and magma genesis in Tokyo, in March 1978.

The Witu Islands are Quaternary volcanoes that overlie the deepest (about 300-580 km) part of the New Britain Benioff zone. The islands are about 100 km south of the transcurrent-divergent plate boundary that crosses the Bismarck Sea, and they surmount the southeastern end of the Willaumez-Manus Rise. The rocks are olivine- and quartz-normative tholeiitic basalts, low- and high-SiO_2 andesites, dacites, and rhyolites. Alkaline rocks that overlie the deep (greater than 300 km) parts of other Benioff zones have not been found in the Witu Islands. Compared to the Witu Islands rocks, those with similar SiO_2 contents from New Britain volcanoes that overlie progressively shallower parts of the Benioff zone to the south, are, for example, generally poorer in Na+K, Ti, and P, and higher in Ca and Al. There are similar progressive changes in trace-element abundances, but Zr and Nb contents are distinctly higher in Witu Islands rocks. $^{87}Sr/^{86}Sr$ values range between 0.70311 and 0.7038, which are typical for rocks from New Britain as a whole and from other island arcs in the southwest Pacific. Two $^{143}Nd/^{144}Nd$ values of 0.512211 and 0.512271, taken together with the Sr isotopic results, define a source region equivalent to those for oceanic-island basalts; there is no evidence for sea-water contamination.

Perhaps the most striking feature of the Witu Islands rocks is their compositional diversity. Basalts range from olivine-tholeiites similar to marginal-basin basalts from other areas, to quartz tholeiites similar in most respects to those typical of island arcs, and to incompatible-element-enriched tholeiites that are close to silica-undersaturation. Andesites on Unea Island have a strong island-arc signature, but the andesites, dacites, and rhyolite of Garove Island have some features that may be more in common with the silica-oversaturated rocks of oceanic areas. The mineralogy of Witu Islands basalts is characterised by phenocrysts of olivine (Fo_{89-54}), plagioclase (An_{90-55}), and Ca-augite. Cr-Al-rich spinels and aluminous magnetites are present as inclusions in some olivine phenocrysts. Groundmass fayalite, alkali feldspar, and dacitic to rhyolitic glasses high in K/Na are found in a few samples. In contrast to basalts from volcanoes above the shallower parts of the New Britain Benioff zone, those of the Witu Islands are characterised by a rarity of low-Ca pyroxene, as phenocrysts or in the groundmass. Rocks richer in SiO_2 are characterised by the presence of orthopyroxene phenocrysts and lesser amounts of olivine. Hydrous minerals appear to be absent. Groundmass Fe-Ti oxides define crystallisation temperatures (about 800-1050 ^{o}C) and oxygen fugacities (fO_2) corresponding to those of the Ni-NiO buffer, but up to two fO_2 log units above it. The suite as a whole is phenocryst-poor compared to most New Britain volcanic rocks.

A significant degree of mantle heterogeneity is inferred by the chemical variability of the Witu Islands rocks. However, there are no compelling reasons in support of the interpretation that source heterogeneity is due to the effect of a slab-derived component. The cause of the heterogeneity is unclear, but may be due to mantle differentiation processes related to an anomalous tectonic setting.

Neodymium and strontium isotopes in New Britain rocks

A study has been completed in conjunction with D.J. DePaolo (Department of Earth and Space Sciences, University of California at los Angeles) on Nd and Sr-isotope ratios and trace-element geochemistry of a suite of eight volcanic rock samples from the New Britain island arc, and is to be reported in a forthcoming issue of Contributions to Mineralogy and Petrology.

The samples range in composition from basalt to rhyolite, and have minimal differences in $^{143}Nd/^{144}Nd$. Small differences in $^{87}Sr/^{86}Sr$ do not correlate with depth to the Benioff zone, but are related to magma type. Nd-Sr isotopic variations suggest that island-arc lavas in general are derived from a mixture of suboceanic mantle and hydrothermally altered mid-ocean-ridge-type basalt, but the New Britain magma source appears homogeneous with little indication of either the involvement of oceanic crust or mantle inhomogeneity. Trace-element patterns in New Britain lavas are not consistent with Nd-isotope data for currently accepted petrologic and trace-element models of magma genesis. Mafic lavas from New Britain and other island arcs have anomalously high Sr/Nd, possibly due to components derived from subducted oceanic crust.

Willaumez-Manus Rise

A study begun in 1977 to determine the origin of the Willaumez-Manus Rise was completed this year with the publication of a paper on this topic in Earth and Planetary Science Letters (co-authors J.C. Mutter, currently at the Lamont-Doherty Geological Observatory, New York, and R.J. Arculus). The rise is aseismic and separates the Manus Basin from the New Guinea Basin. It does not appear to be an extinct spreading axis, or a remnant arc, but may be the result of excess magmatism possibly related to an inferred mantle hot spot beneath St Andrew Strait. A preferred interpretation, however, is that the rise is the raised edge of the New Guinea Basin, formed in response to a thermal anomaly beneath the extensional Manus Basin which formed later than the New Guinea Basin.

Trace-element data acquisition and compilation

A microfilm data Report has been published (co-author B.W. Chappell, Department of Geology, ANU), in which major and trace-element analyses for 210 volcanic rock samples from New Britain and the Witu Islands are compiled in 21 tables. Modal analyses (phenocryst abundances) and locality descriptions, including grid references, are also listed. The catalogue does not include trace-element (mainly rare-earth elements) data obtained by spark-source mass spectrography at RSES/ANU. These determinations were reprocessed during the course of the year to take advantage of improvements to the computer program that converts the raw data - taken directly from the photographic plates - into final results. The new values will be presented in a separate paper currently in preparation.

Planetary Basaltic Volcanism Project

Twelve New Britain basalt samples have been selected as an Island-Arc Basalt Reference Suite for the Planetary Basaltic Volcanism Project being undertaken by the National Aeronautics & Space Administration (U.S.A.). A paper on island-arc basalts is virtually complete, and includes descriptions of the reference suite and a review of the petrology and geochemistry of island-arc basalts in general. The paper is a part of one of several volumes containing the results of the project. S.R. Taylor (RSES/ANU) is senior author of the contribution. Johnson, R.J. Arculus, and M.R. Perfit (RSES/ANU) are co-authors.

Bamus volcano

Bamus is an andesitic stratovolcano similar in size and form to its immediate neighbour, Ulawun, which is one of the most active volcanoes in Papua New Guinea. Bamus, however is dormant, although it may have been in eruption in the late nineteenth century. A study of Bamus has been started to assess its geology, petrology, and eruptive potential, and a report is in progress (co-authors are R.J. Ryburn, R.P. Macnab, B.W. Chappell, and the late R.J.S. Cooke).

The andesites of Bamus are different to those of Ulawun, although both volcanoes overlie the same depth range to the New Britain Benioff zone. Bamus andesites are slightly more felsic than those of Ulawun, but this slight difference in degree of fractionation is inadequate to explain, for example, zirconium being twice as abundant in Bamus andesites. Both volcanoes have grown side-by-side throughout the Quaternary; magma conduits were apparently unconnected, and andesitic magmas were derived independently at each volcano.

Lolobau volcano

The petrology and geochemistry of a suite of rocks from Lolobau Island (northwest of Bamus) is also being investigated - by J. Banner of the State University of New York at Stonybrook. The samples range from basalt to rhyolite, and the object of the study is to test whether all the rocks belong to the same fractionation sequence. Whole-rock analyses and microprobe-determined mineral compositions will be used in conjunction with least-squares mixing programs to assess this possibility.

TABAR-TO-FENI ISLANDS, by R.W. Johnson & D.A. Wallace

Progress has been made on several different aspects of the geochemistry, petrology, and geology of the Tabar, Lihir, Tanga, and Feni Islands (north and east of New Ireland) in conjunction with B.W. Chappell, R.J. Arculus, and M.R. Perfit.

One-hundred-and-sixteen major and trace-element chemical analyses of mainly alkaline rocks have been compiled on cards (together with locality descriptions and grid references) and transferred to magnetic disc in readiness for tabulation in microfiche form. Pyroxene and amphibole separates from four rocks, and one groundmass fraction, were analyses by spark-source mass spectrography for rare-earth elements, and the minerals of about a dozen rock samples were analysed with the microprobe. Papers on Tabar-Feni volcanism were read by Perfit at the Annual Meeting of the Geological Society of America (in Toronto, Canada), and at ANZAAS.

ANZAAS 1979, by R.W. Johnson

Johnson attended the ANZAAS Congress held in Auckland, New Zealand, and presented two papers. The first, 'Late Cainozoic volcanism and tectonics in the eastern Bismarck Archipelago, Papua New Guinea: an overview of recent results' served as an introduction to the second (read on behalf of R.J. Arculus), 'Volcanic rocks of the Witu Islands: the origin of magmas above the deepest parts of the New Britain Benioff zone', and to the paper on the Tabar-Feni volcanism by Perfit.

Johnson was a member of the post-Congress volcanological excursion to the Coromandel Peninsula, Taupo Volcanic Zone, and Alexander Volcanics region, all in North Island. Through the courtesy of the New Zealand Geological Survey he was also able to visit new exposures in the Okataina Volcanic Centre where recent tephrachronological studies have assisted in dating the rhyolitic cumulodomes in the area. Other highlights were ascents of the active volcanoes Tarawera and Ruapehu, and examinations of spectacular ignimbrite sections in the Waikato River.

COMMITMENTS TO IUGG ASSEMBLY, by R.W. Johnson

Special Issue of BMR Journal

A major review entitled 'Geotectonics and volcanism in Papua New Guinea: a review of the late Cainozoic', was completed for the special issue of the BMR Journal being published on the occasion of the seventeenth Assembly of the International Union of Geodesy and Geophysics (IUGG) to be held in Canberra in December 1979. Following is the abstract of the review.

A considerable amount of new information obtained since about 1965 has contributed greatly to a fuller understanding of late Cainozoic tectonics and volcanism in Papua New Guinea. The region straddles a complex zone of convergence between the major Indo-Australian and Pacific plates (estimated rates are about 9-14 cm yr^{-1}), and includes two, and possibly as many as four, minor plates. There are at least six-perhaps as many as ten - plate boundaries in Papua New Guinea. Most of them are zones of convergence, characterised by different components of strike-slip motion; however, one, and part of another, are ridge-transform zones where new sea floor is being created. The Australian continent and Ontong Java Plateau reached the region during the Cainozoic, and may have had a major influence on plate kinematics in the late Cainozoic. Late Cainozoic volcanoes of Papua New Guinea are widely distributed and chemically diverse. Andesite is common, and most volcanic rocks may be classified broadly as arc-trench type; but comendites, intra-plate rhyolites, strongly under-saturated rocks, and basalts similar to those of back-arc basins, are among the rock types represented in some areas.

ICG symposium

Johnson is co-convenor of a symposium, 'Tectonics of the southwest Pacific margins', to be held on 5 December 1979. The symposium is being run by the Inter-Union Commission on Geodynamics (ICG), and Johnson has been involved with organisational responsibilities, partly in connection with the IUGG Local Organising Committee and the ICG representative in Canberra. The disciplines of 20 papers selected for the one-day symposium are: marine geophysics, field geology, geodynamics, petrology, and geochemistry, and the areas covered range from the Caroline Sea to New Zealand. Eight papers deal with tectonic problems in Papua New Guinea.

HIGHLANDS VOLCANIC GEOLOGY, by D.E. Mackenzie

Geochronology

A paper entitled 'Potassium-argon ages from some of the Papua New Guinea Highlands volcanoes, and their relevance to Pleistocene geomorphic history', co-authored by E. Loffler (CSIRO) and A.W. Webb (AMDL), is to appear in a forthcoming issue of the Journal of the Geological Society of Australia.

Isotopic dating of 32 whole-rock samples from seven of the highlands volcanoes shows a wide spread of ages ranging from 1.6 m.y., or possibly 1.9 m.y., to around 200 000 years. These dates together with evidence of recent activity on two volcanoes suggest that the highlands volcanic province has been volcanically active for at least the last 1.6 m.y. and that early volcanism was contemporaneous with intrusive igneous activity in the Star Mountains. Major eruptions of lavas, however, ceased at about 200 000 years and there is evidence from some of the volcanoes of apparent long breaks in activity. Glacial activity on Mount Giluwe may date back to 700 000 years, and certainly to about 300 000 years, indicating that altitudes of present magnitudes must have existed early in the Pleistocene, and that most of the volcanism probably postdates the uplift of the central ranges. Volcanism is also responsible for major changes in the highlands drainage system, but dating of these events is difficult. The isotopic ages are not always consistent with the erosional state of the volcanoes; this also suggests a long and complex history of volcanism in the highlands.

Archaeology

Mackenzie was requested by J.M. Rhoads (ANU) to examine and attempt to identify the source, or sources, of several samples of pottery clay and stone axe-heads excavated in the Kikori-Aird Hills area, Gulf of Papua. None of the clays appeared to be of local origin; most contain a variety of rock and mineral fragments, including volcanic and metamorphic rocks, garnet, and blue amphibole that suggest the Owen Stanley Range, possibly the Tapini area. All the axe-hads except one were made from fine-grained metamorphosed mafic igneous rocks, and many contain blue-green amphibole. One is a muddy chert containing probable Lower Cretaceous radiolaria. The axe-heads probably all come from the same general area, also probably in the Owen Stanley Ranges (Owen Stanley Metamorphics).

OTHER STUDIES FOR EXTERNAL PUBLICATION, by R.W. Johnson

Andesite review

A review of andesitic volcanism in Papua New Guinea has been completed for the book 'Orogenic andesites and related rocks' to be published by John Wiley & Sons and to be edited by R.S. Thorpe.

Andesite is present on most of the 100 or more late Cainozoic volcanoes in Papua New Guinea, and has been produced historically by eight - possibly as many as ten - of the 14 active eruptive centres. All the arch-trench-type volcanoes are grouped roughly into seven provinces, six of which have andesite (the exception is the alkaline Tabar-to-Feni province). Papua New Guinea andesites may be divided into two broad types, one having generally greater contents of incompatible elements, higher $^{87}Sr/^{86}Sr$ values, and more fractionated rare-earth-element patterns, than the other. The origin of the andesites is related to convergent-plate-boundary tectonics, but there is an incomplete correlation between andesitic volcanism and intermediate and deep-focus earthquake activity. This is particularly so in the Highlands and Eastern Papua provinces where chemical modification of mantle source regions by dehydrating downgoing slabs may have taken place much earlier (late Mesozoic or early Tertiary) than the late Cainozoic andesitic volcanism.

Trachytes from Lusancay Islands and Aird Hills

'REE-fractionated trachytes and dacites from Papua New Guinea and their relationship to andesite petrogenesis' is the title of a paper published this year in Contributions to Mineralogy and Petrology, and co-authored by I.E.M. Smith (University of Auckland) and S.R. Taylor.

Minor trachyte and dacite temporally associated with, but spatially separated from, arc-trench type volcanoes in Papua New Guinea have distinctive REE abundances similar to experimentally produced and theoretically predicted partial melts of eclogite. However, modelling based on small amounts of equilibrium partial melting indicates that fractionation involving residual garnet alone can account for the observed REE patterns if the source rock was subducted oceanic basalt. If the source was geochemically evolved, other mineral phases (e.g. amphibole) are possible in the residuum, and there is no necessity to postulate that the downgoing slab was the source for these magmas. The REE fractionated trachytes and dacites appear to be a part of the nearby late Cainozoic volcanic provinces, and possibly represent minor partial melts which only in unusual tectonic situations arrive unmodified at the Earth's surface.

Amphibole-bearing inclusions of Boisa Island

Rocks from Boisa (or Aris), a small volcanic island near Manam volcano off the north coast of New Guinea, are being studied in collaboration with D. Gust (RSES/ANU). The island is andesitic, and is of particular interest because of its amphibole-bearing inclusions, and because of a well-defined temporal change in andesite compositions: low-silica andesites are overlain by high-silica andesites.

Microprobe-determined compositions were used in least-squares mixing calculations to determine a compositional relationship between the older and younger andesites and the cumulates on Boisa. However, a closer match between the two lava types has been obtained using phenocrysts compositions than using the compositions of minerals in the amphibole-bearing inclusions.

Reversal of arc polarity in eastern New Guinea

There was an opportunity during the year to incorporate the significance of recent results into the paper 'Continent-arc collision and reversal of arc polarity: new interpretations from a critical area', presented in February 1976 at the Carey Symposium in Tasmania (publication of the symposium proceedings has been delayed). However, the main conclusions of the study, co-authored by A.L. Jaques, remain unchanged.

Northern New Guinea has been regarded as a region where the polarity of an island arc reversed following collision with the Australian continent in the Tertiary, but 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 early vertically. The active marginal basin lying to the north of the arc, 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.

PETROLOGICAL, GEOCHEMICAL, AND GEOCHRONOLOGICAL LABORATORIES

Supervising geologist: John Ferguson

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

Technical Staff: G.W.R. Barnes (to June), M.J. Bower, N.J. Davis, J. Duggan, K.H. Ellingsen, J.I. Fitzsimmons, N.C. Hyett, C.R. Madden, J.G. Pyke, T.I. Slezak, T.K. Zapasnik

PETROLOGY LABORATORY

ALKALINE ULTRAMAFIC ROCK PROJECT, by John Ferguson, J. Knutson, R.J. Arculus (ANU), and J. Joyce (Stockdale Prospecting Ltd)

Fifteen widely separated occurrences of kimberlite and kimberlitic rocks are now known in southeastern Australia. Those that have been satisfactorily dated isotopically give ages ranging from Permian to Late Jurassic.

Location of the kimberlite intrusions appears to be related to a number of general structural factors such as the presence of folds, faults, and lineaments. Most intrusives are located in belts of present-day seismic activity. The kimberlitic intrusions of New South Wales and Victoria are also associated with a broad zone of epeirogenic uplift, and coincide with the mean migration path of a postulated Cainozoic hot-spot. A number of these features are younger than the age of kimberlitic intrusion, and any casual relationships are unclear.

The classification of these generally altered rocks as 'kimberlitic' is partly based on their mode of emplacement, and particularly on the presence of crust/mantle inclusions. Compared to African kimberlitic magmas, the southeastern Australian examples have lower incompatible-element contents. These differences are interpreted as representing slightly greater degrees of partial melting of a four-phase lherzolite assemblage at shallower depths than typical African kimberlite magma. Projections of chemical data onto planes within the CaO-MgO-Al_2O_3-SiO_2 system, and comparisons with experimental data, suggest that the magmas were generated at about 65 km depth. Observed fractionation trends of the kimberlitic magma compositions are consistent with minor olivine, and possibly orthopyroxene, fractionation.

Upper-mantle nodules in some of the intrusives include spinel, garnet-spinel, and garnet lherzolite; rare griquaite nodules are found in one pipe at Jugiong. Crustal nodules include garnet clinopyroxenite, eclogite, websterite, and salic granulite. Most of the mafic crustal nodules are of basaltic compostion, and may represent slightly altered, high-pressure, metamorphic equivalents of erupted basalt types, as well as cumulates from basalt magma. None of the salic nodules correspond to the type of source or restite hypothetically involved in granite genesis.

P-T estimates for the nodule assemblages give a maximum source depth of $\sim$ 70 km, and temperatures of $\sim$ 1240 $^{\circ}$C. They also indicate unusually high geotherms at the time of pipe generation, and the calculated geotherms all exceed the estimated mean oceanic geotherm. The abnormally high geothermal gradient implied by most of these data intersects the graphite-diamond stability curve at considerably higher temperatures and pressures than those indicated by the nodules. If the P-T conditions indicated by these calculations represent a steady-state rather than a transient geotherm, it is unlikely that diamondiferous kimberlites of Permian or younger age exist in most of southeastern Australia. An exception is the Eurelia (South Australia) province, where the rocks are considered on other evidence to have been formed at depths > 125 km.

The combined results of seismic and kimberlitic nodule studies give a coherent model of the crust-upper mantle structure in southeastern Australia. The presence of basaltic lower crust in granulite facies produces mineralogical phase changes that can account for the gradual change in P-wave velocity across the crust-mantle interface without the development of a Moho.

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

Petrographic and geochemical studies of rocks from Enderby Land and MacRobertson land continued, in conjunction with the geological field research programme in Enderby Land. Most of the analytical work has now been completed and the results are being written up for publication.

Mafic igneous rocks (J.W. Sheraton, R.N. England (Monash University), A. Cundari (University of Melbourne))

Proterozoic tholeiitic dykes are widespread in Enderby Land, the southern Prince Charles Mountains, and the Vestfold Hills, and apparently represent a related suite which extends for at least 1200 km.

Representatives of at least four distinct magma types have been recognised in Enderby Land. Two groups of quartz tholeiites with generally similar major-element compositions are present, one characterised by relatively high TiO_2 and incompatible elements (K, P, Rb, Sr, Zr, Nb, Ba, La, and Ce). Rare olivine tholeiites show marked iron-enrichment and have high K_2O, Nb, and Ba. The remaining group consists of magnesian dykes, ranging from norite to hypersthene-bearing quartz tholeiites, and relatively enriched in some incompatible elements (notably Pb, Th, U, and As), but depleted in P_2O_5 and Nb. The high MgO, Ni, and Cr contents of the norites suggest that they represent near-primary magmas, similar to liquids produced by hydrous melting of pyrolite at around 15 kb. The more siliceous rocks of this group (about 8% normative quartz) may have been derived from a magma of similar composition to the norites by fractionation initially dominated by olivine, then by orthopyroxene and probably clinopyroxene.

Dykes from the Vestfold Hills include olivine tholeiites, quartz tholeiites, and Mg-rich hypersthene tholeiites, whereas those (mostly amphibolitised) from the southern Prince Charles Mountains comprise quartz tholeiites and subordinate olivine tholeiites. Rare mafic dykes which intrude late Proterozoic (900-1100 m.y.) metamorphics of the northern Prince Charles Mountains and MacRobertson land coast are alkaline (alkali olivine basalt, together with a tristanite lava) or have alkaline affinities. Those dated have given Phanerozoic ages.

Two isolated examples of alkaline mafic dykes from Enderby Land and the southern Prince Charles Mountains consist of K-richterite, phlogopite, K-feldspar, and apatite, with accessory anatase, rutile, sphene, barite, and zircon. Both belong to the rare potassium-rich volcanic and sub-volcanic rock suite, and are characterised by extremely high K_2O (8-10%), TiO_2, P_2O_5, Ba, Sr, and Zr. That from Enderby Land is relatively magnesian, has higher Cr and Ni contents, and probably represents a near-primary magma, whereas the other, which has given a Silurian age, is more evolved (quartz-normative) and shows evidence of liquid immiscibility. A short paper on these alkaline dykes (with R.N. England) has been submitted to the Journal of the Geological Society of Australia, and a paper (with A. Cundari) on the K-rich leucitite lavas of Gaussberg, Wilhelm II Land, has been completed.

Metapelites (J.W. Sheraton)

A paper on the geochemistry of metapelites from Enderby Land and MacRobertson Land is being written for submission to the BMR Journal. Early Archaean (>3.0 b.y.) granulite facies metapelites from the Napier Complex of Enderby Land are considerably more magnesian and (on average) more K-poor than those from MacRobertson Land which range from late Archaean to late Proterozoic in age and are of amphibolite to granulite grade. This may reflect a higher proportion of mafic to ultramafic rocks in the early Archaean source. Granulite facies metapelites are depleted in U and probably Th compared with amphibolite-facies analogues, and high-temperature granulite facies metapelites from the Napier Complex are also relatively depleted in Rb. Unique (on a regional scale), very high-temperature associations sapphirine + quartz and osumilite in the Napier Complex are confined to magnesian metapelites (Mg >0.55), and the fact that such compositions are relatively common has thus been an important factor in the development of these assemblages.

Felsic gneisses (J.W. Sheraton)

Felsic orthopyroxene-quartz-feldspar gneisses are widespread in the Archaean Napier Complex of Enderby Land. They range in composition from tonalitic to granitic, although tonalite and granodiorite gneiss are the most abundant, in common with other Archaean high-grade terrains. As a group, they are depleted in Rb (relative to K), Th, and U, and show variable depletion in Y (which also implies depletion in heavy rare-earth elements). The chemistry of the more sodic gneisses is consistent with an origin by partial melting of a mafic source, leaving garnet in the residue, although a two-stage model, possibly involving melting of tonalitic to granodioritic source rocks, may be necessary to explain the chemistry of the more potassic, granitic gneisses.

Garnet-bearing felsic gneisses are generally of granitic composition, and are either of direct sedimentary origin, or were derived by partial melting of metasediments. They are corundum-normative, and associated with a variety of undoubted metasediments.

ARCHAEAN MANTLE GEOCHEMISTRY, by A.Y. Glikson

A study of a komatiite lava suite from the about 3.5-b.y.-old lower Onverwacht Group, Barberton Mountain Land, South Africa, led to the following conclusions:

Progressive depletion of several Archaean volcanic sequences in siderophile (Fe, Ti, Mn, V, Co), lithophile (Zr, Sr, P, Y), and chalcophile (Zn, Cu) elements with higher stratigraphic level are reported for this volcanic sequence, in agreement with observations in the eastern Pilbara Block (Western Australia), a number of sequences in the Yilgarn Block (Western Australia), and the Superior Province of Canada. These trends are shown by both high-Mg basalts and tholeiitic basalts, and are not dependent on the Mg number of the rocks. Because these variations are in contrast to the Skaergaard-type iron enrichment trend, and as they are unlikely to have been produced by secondary alteration, it is suggested they reflect secular depletion of source mantle regions following repeated extraction of basic partial-melt fractions. High-Mg basalts and peridotitic komatiites of the Tjakastad Subgroup are separated by compositional gaps in MgO, Al_2O_3, CaO, Ni, and Co, as well as on the Ol-Op-Cp-Qz diagram, which militate against their relation by continuous crystal fractionation. Archaean high-Mg basalts are typically quartz-normative, as distinct from picrites. Using the FeO-MgO (mol %) diagram, liquidus temperatures are estimated for the high-Mg basalts and komatiitic peridotites. The degree of partial melting (F) is deduced by mass balance calculation of FeO + MgO. Assuming olivine-dominated residues of partial melting, and using temperature-dependent K_d^{gO} and K_d^{eO} coefficients after Roeder & Emslie

(1970), the mantle Mg number can be estimated. For the Archaean data, source Mg numbers fall mainly in the range 80-90, suggesting a relatively ferroan mantle. Computations of mantle trace-element levels are attempted, assuming equilibrium batch melting, residual normative mineral assemblages, and applying cited mineral-melt partition coefficients (D). The possibility of an Archaean mantle rich in iron, and possibly other siderophile elements, is supported by comparisons between Archaean and modern oceanic tholeiites. The distribution of mantle-melting events in space and time must have resulted in significant major- and trace-element heterogeneities. Subsidence of dense refractory mantle residues into undepleted regions may have triggered mantle diapirism, probably constituting a factor underlying Archaean tectonic activity. The results were published in the BMR Journal IUGG issue.

The results of a major review and comparative geochemical study of Archaean tonalites and trondhjemites were published as a paper in Earth Science Reviews, entitled 'Early Precambrian tonalite/trondhjemite sialic nuclei'. A paper entitled 'The missing Precambrian crust' was published in Geology, discussing sial-sima distribution models during the early and middle Proterozoic, with implications for the radius of the Precambrian Earth. The publication is pending of a more extensive discussion of this subject in Tectonophysics, entitled 'Precambrian sial-sima relations: evidence of Earth expansion?'. A joint paper with J.A. Hallberg (CSIRO, Perth) is in press, entitled 'Archaean granite-greenstone terrains of Western Australia'. A Sm-Nd age of 3.52 ± 0.06 b.y. (initial $^{143}Nd/^{144}Nd$ of 0.508139) was reported by J. P.J. Hamilton (Lamont Doherty Geological Observatory, Columbia University) for volcanic rocks of the Talga-Talga Subgroup, eastern Pilbara Block, on material forwarded by A.Y. Glikson. This age, the oldest reported in Australia, accords well with the U-Pb zircon age of 3.45 ± 0.016 b.y. reported for the overlying Duffer Formation by Pidgeon (1978), and with younger U-Pb zircon ages of intrusive trondhjemite.

PILBARA GEOCHEMICAL STUDY, by A.Y. Glikson & A.H. Hickman (GSWA)

Phase 1 of the joint BMR-GSWA project was completed during the first half of 1979. The work included the writing of several petrochemical computer programs, including (1) IMPR plots and deviation indices; (2) mantle Mg number calculation; (3) mantle trace-element levels computations; (4) equilibrium partial melting calculations: (5) fractional crystallisation and primary magma trace-element levels. The data were also computed according to R-mode factor analysis, cluster analysis, and the CMAS tetrahedron program. A draft of a Record entitled 'Geochemistry of Archaean volcanic successions, eastern Pilbara Block, Western Australia' was written and sent to the GSWA for addition and comment. A summary of the principal result follows.

The major and trace element study of 465 volcanic rocks from the eastern Pilbara Block allows construction of a regional geochemical stratigraphy and insight into the petrogenesis and evolution of the Archaean crust. Unique geochemical characteristics of individual units facilitate the use of major and trace element criteria as stratigraphic guides for identification of isolated volcanic outcrops. A screening method designed for altered samples, using LMPR (log molecular proportion plots) indicates considerable mobility of alkali and alkaline earth elements, but relative stability of siderophile elements (Fe, Ti, Mn, V), some LIL (large-ion lithophile) elements (P, Zr, Nb, Y), and magnesian-related elements (Ni, Cr, Co).

The 3.50b.y.-old Talga-Talga Subgroup (TTS) - the oldest sequence known in the Pilbara Block - is dominated by tholeiitic basalt and dolerite high in Ti and low in K, Al, Ni, and Cr. Quartz-normative high-Mg basalts and some peridotitic komatiites are closely interspersed with the tholeiites. Lenses of high-Al dacite-andesite occur between the basic North Star Basalt and Mount Ada Basalt (the two principal units of TTS). The overlying Duffer Formation (3452 ± 16 m.y. - Pidgeon, 1978a) consists of predominantly-pyroclastic calc-alkaline Na-dacite, K-dacite, Na-rhyolite, K-rhyolite, andesite, minor tholeiitic basalt and dolerite, and pyroxenite. Upper greenstone sequences of the Salgash Subgroup (SS) consist of a lower basic unit in places accompanied by peridotitic komatiites (Apex Basalt) and an upper unit of tholeiitic and high-Mg basalts (Euro Basalt). Minor dacite-rhyolite lenses (Kelly and Panorama Formations) occur. The Wyman Formation, at the top of the Warrawoona Group, consists of ultrapotassic quartz porphyry. Tholeiitic basalt intercalations in the overlying clastic sediments of the Gorge Creek Group (Charteris Basalt, Honeyeater Basalt), have high K and Al and low Ti. A secular depletion in Fe, Ti, P, Zr, and Y is shown by the volcanic successions, constituting both an overall trend and repeated smaller-scale cycles. As these trends are not explicable in terms of magmatic fractionation, it is suggested they reflect depletion of the mantle in siderophile and lithophile components as a result of repeated partial melting.

Most of the basic volcanics plot within least-altered modern volcanic fields, whereas silicic volcanics commonly display Ca depletion. Correlation coefficients, frequency distributions, and stratigraphic variations suggest high Ca, Na, K, Ba, Rb, and Sr mobility, but a relative stability of siderophile elements (Fe, Ti, Mn, V), magnesium-related elements (Ni, Cr, Co), certain lithophile elements (P, Zr, Nb, Y), and in some instances rare earth elements (Ce, La) and chalcophile elements (Cu, Zn). A concentration toward the top, of sequences of volatiles, alkalies, and Cu is attributed to either synvolcanic carbonatisation and/or secondary upward migration associated with leaching of copper from the basic volcanic rocks.

Petrogenetic calculations suggest iron-rich mantle source compositions (Mg number in the range 80-90). Peridotitic komatiites formed by over 50-percent melting of mantle peridotite, representing high-temperature diapiric events. As suggested by compositional gaps between peridotitic komatiites and high-Mg basalts, these magmas were not likely to be related to crystal fractionation. High-Mg basalts were formed by 30-50-percent melting of mantle periodotite in a shallow (about 60 km) Archaean low-velocity zone. As suggested by the continuous chemical spectrum between high-Mg basalts and tholeiitic basalts, the latter formed from high-Mg basalt magma by 25-65-percent crystal fractionation of clinopyroxene, olivine, orthopyroxene, and minor plagioclase. low-LII dacites of the Duffer Formation formed by partial melting of basic source materials - possibly equivalent to the Talga-Talga Subgroup. Hydrothermal addition of Si and K is required to explain the chemistry of the rhyolites. Elvan-type quartz porphyries of the Wyman Formation were probably related to late-stage pneumatolitic hydrous activity. High potassium levels of tholeiitic basalts of the Gorge Creek Group probably represent effects of sialic contamination. Geochemical similarities are indicated between Talga-Talga Subgroup tholeiitic basalts and modern mid-ocean ridge basalts (MORB), and between Gorge Creek Group tholeiitic basalts and arc-trench or Andean high-Al basalts. These features suggest a progressive crustal thickening during the Archaean, i.e. from a simatic to a continental or continent-margin regime. Differences between the Talga-Talga Subgroup basalts and MORB include the high Ti and low Cr and Ni of the former. No strictly uniformitarian interpretation of the geochemical data appears to be justified.

GOAT PADDOCK CRYPTOEXPLOSION STRUCTURE, WA, by J. Ferguson

This project is being jointly undertaken with J.E. Harms (B.H.P.) and D.J. Milton (USGS).

Goat Paddock is a crater slightly over 5 km in diameter excavated in Proterozoic sandstones and siltstones at the north edge of the King Leopold/ Mueller Range in the Kimberley District, WA, centered at 18°20'S, 126°40'E.

The topographic expression is a plain rimmed by cliffs and steep slopes 100 to 150 m high that form a circle except for a break in the north and a smaller one in the west. To the east and south the ground rises behind the cliffs into the Range so that a raised rim is not obvious. Two drill holes, one at the centre and one about 1250 m northeast, penetrated ~200 m of lacustrine sediments before entering strongly shocked and brecciated sandstone. The equal depths indicate the absence of a central peak, which might have been expected, as 4 km is usually taken as the critical diameter for the simple to complex transition for terrestrial impact craters.

The lower crater walls are concealed by the lake beds but the gulches and canyons eroded into and through the walls of the Paddock exhibit perhaps the best exposures of the upper crater wall of any impact crater in the world. No fallout (air-sorted debris) was found and we are uncertain whether or not the breccia at high levels includes throwout (debris ejected ballistically), but the upper walls, rim crest area, and at least inner rim are little modified by erosion in many sections. Bedrock, initially dipping rather uniformly 15° NNW, is upturned to dip away from the crater nearly everywhere in the walls, reaching the vertical along much of the crater rim, and is overturned to the horizontal or beyond farther out. The rim in some sections appears to be composed of imbricate plates a hundred metres or so across, moderately dipping and presumably overturned, separated by screens of breccia. The outer limit of the intensely disturbed rock lies as far as 1000 m from the apparent rim crest and is, in places, abrupt. At one locality a fault surface dipping 75° toward the crater with striations pitching 75°, separates apparently undisturbed sandstone from overturned sandstone.

The disturbed beds everywhere show a high degree of fracturing, and grade into breccia inside and particularly outside the crest. At many occurrences of breccia the larger clasts continue the attitudes of nearby coherent bedrock and the matching of clasts shows that little mixing or long distance transport has occurred.

The inner wall at the edge of the upturned beds has a slope of 35° or as much as 50°. Breccia immediately adjacent may consist of unoriented clasts but generally grades, over a short distance, into a roughly oriented texture, that apparently represents talus. Above this there is a conglomerate with clearly rounded clasts and fairly well developed bedding. The transition is locally gradational, but more commonly there is a discordant relation, with conglomerate dipping 20° above talus dipping 35°. The conglomerate in turn grades into grit, and, on a hill that projects into the crater circle on the west, shows the further transition to siltstones. It appears that the crater fill shows a gradual facies change from the coarsest conglomerates to the mudstones of the drill cores.

Conglomerate (and breccia) occupies not only the outer edges of the crater bowl, but also other depressions outside the main crater wall. Some of these appear to be crescentric lows concentric with the crater rim. In one section the series of overturned plates appears to be displaced outward to produce a double rim crest, with breccia and conglomerate filling a gap between the outer edge of upturned bedrock and the inner edge of the displaced plates. Other conglomerate bodies appear to be approximately radial rather than concentric. These may occupy zones opened during impact or they may be fill in pre-impact valleys, perhaps with drainage blocked by the crater rim. There is no reason to suggest that the local topography differed in character from the present topography, and the level at which irregularities in the ground surface would have been of significance during impact is certainly preserved.

The steepness of the crater wall decreases markedly at about the level of the Paddock plain. Overturned bedrock crops out at several points as far as 350 m from the base of the cliff. In one watercourse at the south suevite (shock-metamorphosed breccia) occurs about 200 m out from the base of the cliff.. The substrata is not exposed but the suevite is apparently on a gently sloping crater wall, as melted clasts lie approximately horizontally and bedrock crops out about 150 m farther inward.

STRANGWAYS CRYPTOEXPLOSION STRUCTURE, NT, by John Ferguson

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

The Strangways cryptoexplosion structure is a circular feature containing abundant evidence of shock metamorphism. The core consists of granite gneiss about 10 km in diameter, surrounded by a collar of Proterozoic quartzite and siltstone. No definitely coherent bedrock is exposed in the core: exposures are breccia, commonly highly shocked, or melt rock rich in clasts. In different areas the clasts may be all of gneiss, or a mixture of gneiss and sediments. In the collar, which is about 5 km wide, quartzite forms ridges of steeply dipping, outward-facing strata, which commonly extend outward into overturned flaps, presumably lying on poorly exposed siltstone. In one sector the outermost quartzite forms a flap of nearly horizontal overturned beds 4 km wide, making the diameter of the disturbance about 22 km. The innermost quartzite is mainly breccia, both in the strike ridges and flaps; breccia is minor in the outer quartzite ridges. Shatter fracturing - more commonly intersecting sets of striated cleavage surfaces than well-formed cones - is well developed in the inner quartzite of the collar, but rare toward the outside. Anomalous features are small patches or house-sized blocks of at most weakly shocked quartzite resting on gneiss up to 1.5 km inside the normal contact, and rare blocks of shocked gneiss as far as 0.5 km outside. In the northwest corner of the structure a flat-lying carbonate unit is found which appears to post-date the explosive event and is possibly the Cambrian Tindall limestone.

The basic structure is similar to the Vredefort Dome in South Africa, but the melt rock and the flaps indicate a shallower level of exposure. The occurrence of the flaps at about the same elevation as the base of the melt layer is surprising. It is not clear whether they represent features of the collar rocks outside the central uplift or of the floor inside.

The presence of shatter-cones, diaplectic glass, and planar decorations in quartz indicates a high-degree of shock metamorphism. Extrapolation of static experimental data suggests pressures could have been as high as 100 kb. To achieve pressure on this scale at high levels in the crust would require the impact of a meteorite or comet; the chemistry of the shattered and melted rocks is, however, enigmatic. Relative to the undisturbed rocks they show enrichment in the compatible elements Ni, Co, Cr, and V and in the incompatible elements Ba, La, Ce, P, and Ti. Large-scale introduction of K has also taken place. Although the compatible elements could be attributed to volatilisation of a meteorite during impact, the introduction of K and the incompatible elements would not support such an origin. If the shock-metamorphism observed is to be attributed to a terrestrial origin a violently explosive crypto-volcanic event would be the most likely cause. The chemical changes recorded suggest involvement of a volatile-enriched alkaline ultramafic magma. The biggest difficulty facing the argument for a terrestrial origin would be in the generation of excessively high overpressures, as suggested by the experimental work.

PINE CREEK GEOSYNCLINE, NT, by John Ferguson, G.R. Ewers, T.H. Donnelly (CSIRO), & A.G. Rossiter

The Alligator Rivers uranium deposits are stratabound within the lower Proterozoic Cahill Formation. Quartz-muscovite-chlorite schists predominate in all deposits. Within areas of uranium mineralisation, chloritisation is intense, with the partial or complete relacement of biotite, muscovite, garnet, amphibole, and feldspar. The two most striking features common to the ore zones of all deposits are the tendency for mineralisation to occur within zones of brecciation, and for it to be intimately associated with the chlorite cementing these breccias. The breccia fragments are typically chloritic and/or sericitic quartzite, chert (which in places is silicified carbonate) and strongly chloritised material. They are usually angular, laminated, and rotated. The textures and lithology indicate that brecciation occurred after the ~1800 m.y. regional metamorphic event, and that there was a high percentage of voids between the fragments. Breccia fragments have been cemented by chlorite ± quartz ± hematite ± chert ± graphite ± sulphides ± uraninite. The primary uranium mineralisation is uraninite, though brannerite, and coffinite have been reported. The uraninite occurs as disseminated cubes, which may coalesce to form clusters and strings; veins coating foliation planes; narrow lenses; rare spherules; and massive uraninite. Textures establish that uranium has been remobilised and redeposited within the ore zones. The limited extent of carbonaceous and sulphide-rich zones and their poor correlation with uranium mineralisation suggest that any deposition of uranium as a result of reducing conditions, has been localised rather than widespread.

The textural relations and composition of the chlorite cementing the breccia fragments vary considerably, and their significance in terms of ore genesis is open to interpretation. It is suggested that the presence of gibbsitic material, clay minerals, and clay-sized chlorite in this fracture-filling chlorite may indicate an environment in which uranium was concentrated through adsorption. The tendency for the Fe^{2+}/Fe^{3+} ratio of the chlorite cementing breccia fragments to decrease with increasing whole-rock uranium values, suggests that redox reactions involving Fe may have led to uranium deposition.

As part of a wider magnetics and stable-isotope study (involving D.H. Tucker, Ewers, and T.H. Donnelly), the opaque mineralogy of a suite of rocks from selected drillholes across the Pine Creek Geosyncline has been described. The samples are mainly amphibolite and carbonaceous shale, and come from rock units giving a strong magnetic response. It has been found that in the Litchfield and Alligator Rivers areas, the magnetic response is largely due to the presence of magnetite, whereas in the central area of the geosyncline it is due exclusively to pyrrhotite. On the eastern side of the geosyncline the transformation from pyrrhotite to magnetite appears to correlate with an abrupt change in metamorphic grade observed by Ferguson and Needham. Some of the results of this work have been published in the Bulletin of the Australian Society of Exploration Geophysicists (Tucker et al., 1979).

OPHIOLITE AND BASALT PETROGENESIS, by A.I. Jaques

Results of detailed petrological and geochemical studies of Papua New Guinea ophiolites were compiled and several papers are either complete or are in advanced stages of preparation. The ophiolite belts of Papua New Guinea are of interest both economically in view of the associated lateritic Ni mineralisation and alluvial chromite and platinum-group metals, and scientifically in understanding the formation of ocean basins and marginal seas. A synthesis of the data on ophiolites will be presented at the IUGG, to be held in Canberra in December 1979 and the SW Pacific Symposium to be held in Sydney, immediately after the IUGG.

Results of experimental studies of the petrogenesis of ocean-floor basalts were integrated, and three papers have either been submitted for publication or are published.

The petrology and petrogenesis of cumulate peridotites and gabbros from the Marum ophiolite complex, northern Papua New Guinea, by A.I. Jaques

This paper presents a detailed study of the mineralogy and petrology of the crustal cumulates (ranging from dunite at the base through lherzolite, pyroxenite, and norite gabbro to anorthositic gabbro at the top) exposed in the

Marum ophiolite. Well developed layering and cumulus textures indicate an origin by magmatic crystallisation in a large magma chamber, but most rocks show textural and mineralogical evidence of extensive sub-solidus re-equilibration. Compositional changes in the cumulus phases are established by microprobe and are compared with data from stratiform intrusions. Calculations using various geothermometers and geobarometers, and thermodynamic reactions involving silica buffers, indicate crystallisation at low pressure (1-2 kb) and high temperature (1300-1200 °C). An estimate is made of the parent magma composition, and the Marum cumulates are compared to similar sequences in other ophiolites and layer 3 of the oceanic crust.

Petrogenesis of mid-ocean ridge basalts, by D.H. Green, W.O. Hibberson, & A.I. Jaques

The crystallisation behaviour of a primitive, mid-ocean ridge basalt from Leg 3 of the Deep Sea Drilling Project was studied experimentally at pressures up to 15 kb. These and complimentary experiments showed that this basalt is not a primary segregated type but was derived from a picritic parent basalt and from residual harzburgite at about 20 kb and 1430 °C. These results showed that there can be no simple relationship between tholeiitic picrite parent magmas and the residual harzburgite and cumulate peridotites and gabbros found in ophiolites. These results have led to the abandonment of earlier models for the genesis of mid-ocean ridge high-alumina olivine tholeiites. The paper 'Anhydrous melting of peridotite at 0-15 kb pressure and the genesis of tholeiitic basalts', by A.I. Jaques & D.H. Green, was delivered in absentia to the IAVCEI symposium on ophiolites held in Cyprus in May.

The anhydrous melting behaviour of two model upper mantle compositions, pyrolite and spinel lherzolite, were studied experimentally at temperatures ranging from near to about 200 °C above the solidus at 0-15 kb pressure. Melting occurs in four main melting fields in which an Al-rich phase (plagioclase at low pressure, spinel at moderate pressure, and garnet at high pressure) followed by clinopyroxene followed by orthopyroxene are progressively melted with increasing temperature to leave a dunite residue. Microprobe analyses of the residual phases show progressive changes to more refractory compositions from melting of pyrolite in the spinel peridotite field range from alkali olivine basalt through olivine tholeiite to picrite to komatiite, with increasing degree of melting. Melting in the plagioclase peridotite field produces magnesian quartz tholeiite and olivine-poor tholeiite, and, at higher degrees of melting, komatiite.

Experimental petrology and petrogenesis of a marginal basin basalt, by A.I. Jaques & D.H. Green

The crystallisation behaviour of basalt modelled on the composition of a basalt from the Lau Basin was studied experimentally from 0-15 kb. As with the DSDP basalt the crystallisation behaviour of the Lau Basin basalt is not compatible with direct derivation from the upper mantle but indicates significant olivine fractionation before eruption. Experimental studies on a picritic parent composition suggest segregation from a lherzolitic residue at about 70 km depth.

X-RAY DIFFRACTION, by J. Fitzsimmons

468 samples were analysed by X-ray diffraction in the year ending 15 October, 1979.

The major contributors of samples were -

(1) D. Blake - Rock samples from Duchess, Qld (11%)
(2) R. Shaw - A variety of types of samples from central Australia (11%)
(3) B. Bubela - Synthetic mineral samples from the mark 4 tank (9%)
(4) A. Rossiter - Heavy-mineral samples for Forsayth 1:100 000 Sheet (8%)
(5) R. Burne - Evaporite minerals from Spencer Gulf (8%)
(6) B. West - Carbonates from the Great Barrier Reef (7.5%)
(7) I. Withnall - Siltstones and carbonates from Candlow, Georgetown, Qld (6%)
(8) P. Duff - Clay samples from Moonie, Qld (6%)
(9) Z. Horvath - Kerogen samples (5%)
(10) T. Donnelly - Sulphide samples from Pine Creek, NT (5%)

D. Barnes was the Officer-in-Charge of XRD until 18 August, 1979. At that time J. Fitzsimmons took over the position and has continued to this date.

CHEMISTRY LABORATORY

GEOBOTANICAL AND SOIL GEOCHEMISTRY OVER THE RANGER 1 NO. 3 OREBODY, by B.I. Cruikshank & J.G. Pyke

Although geobotanical sampling as an aid to prospecting is well established internationally, little has been published on the geobotanical behaviour of uranium in the Australian environment. This project aims to validate the application of geobotanical techniques in the search for uranium in the Pine Creek Geosyncline.

The Ranger 1 No. 3 orebody was selected as the site for the study because the cover is typical of much of the Pine Creek area and the orebody, although well-defined by auger and diamond drilling, is relatively surficially undisturbed. Soil samples from the auger grid over the orebody were provided by Ranger Uranium Mines to act as the control for the geobotanical sampling, and will be analysed for a range of elements.

All major species of vegetation growing within the area of the soil grid and known to be widespread in the area were sampled, as was vegetation of the same species in areas considered to be barren in uranium. These ranged in size from <u>Eucalyptus tetrodonta</u> (stringybark), known to have a deep tap root, to large shrubs. Where practical, leaves, twigs, fruit, bark, and trunk wood were sampled to ascertain which gives the largest and most reliable anomaly. Replicate samples of some of the larger species were collected to determine the reproducibility of the techniques.

No analyses are yet available from the material collected.

<u>PETROCHEMICAL STUDY OF LOWER PROTEROZOIC SEDIMENTS OF THE PINE CREEK GEOSYNCLINE, NT</u>, by G.R. Ewers

The objectives of this study are to:

1) establish a data base for different rock types within the various Lower Proterozoic units of the Pine Creek Geosyncline. It may even be possible to fingerprint certain formations chemically and contribute to an understanding of the stratigraphy.
2) investigate how changing metamorphic grades across the geosyncline have affected the chemistry of the sediments.

Wherever possible the study is making use of core samples taken from below the weathering zone and obtained during stratigraphic drilling in unmineralised areas. The work is being carried out in collaboration with members of the Pine Creek party. It is too early at this stage to report any results.

ORIENTATION GEOCHEMICAL SURVEYS, by P.A. Scott & C.R. Madden

Orientation surveys are designed to determine the potential of regional geochemical surveys for resource assessment of metallogenic provinces. In such investigations the parameters relating to sampling techniques, sampling media, trace-element dispersion, sampling density, and any other factors relevant to the regional survey are thoroughly examined.

Processing of the data from the McArthur River Basin survey continued. Base maps at 1:25 000 scale of the area surveyed have been compiled and sample locations plotted.

A preliminary investigation of geochemical dispersion of base metals in the Pine Creek Geosyncline was carried out in 1979. Samples were collected from areas of mineralisation and selected geological units. Sampling media were examined primarily to assess the potential of stream-sediment sampling; unfortunately this technique is not particularly applicable owing to the climate of the region and lack of relief over a large portion of the area. Previous investigations are being assessed.

REGIONAL STREAM-SEDIMENT SURVEYS, by A.G. Rossiter & P.A. Scott

Regional geochemical surveys are undertaken by the BMR to assist in the mineral resource assessment of selected areas through studies of the distribution of anomalous concentrations of various trace elements within a region.

Progress on the six 1:100 000 Sheet areas sampled to date is indicated in Figure M14. The geochemical maps for SEIGAL and HEDLEYS CREEK (NT-Queensland border area) are currently being printed and will be released shortly. Computer processing for GILBERTON, GEORGETOWN (north Queensland), and MAMMOTH MINES (northwest Queensland) continued. The analytical data, accompanied by a sample locality map, are currently being compiled for SEIGAL, HEDLEYS CREEK, GILBERTON, and GEORGETOWN, to be released on microfiche.

ARALUEN GEOCHEMICAL PROJECT, by S.E. Smith & B.I. Cruikshank

The geochemical survey of the ARALUEN 1:100 000 Sheet area commenced in the latter half of 1977 and was planned to extend over the 1977-78 and 1978-79 field seasons. The object was to obtain an understanding of geochemical dispersion patterns in temperate terrains, with possible spin-offs for regional geological mapping and assessment of the economic potential of the area.

1:100 000 SHEET NAME	COLLECTION OF SAMPLES	CODING OF FIELD DATA	CHEMICAL ANALYSIS OF SAMPLES		CODING OF ANALYTICAL DATA	PUNCHING OF COMPUTER CARDS	DATA IN STORAGE/ RETRIEVAL SYSTEM	DIGITISING		CARTOGRAPHY		PRINTING OF MAPS	PREPARATION OF REPORT
			AAS	XRF				SAMPLE POSITION	GEOCHEMICAL SYMBOL POSITION	AUTOMATED	MANUAL		
FORSAYTH (QLD)													
SEIGAL (NT)													
HEDLEYS CREEK (QLD)													
GILBERTON (QLD)													
GEORGETOWN (QLD)													
MAMMOTH MINES (QLD)													

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

The map area can be divided into two distinct parts:

(i) tableland area consisting of gentle to moderately steep undulating country with deep soil development, and
(ii) coastal escarpment area which is deeply-incised, very steep country with little soil development.

It was decided that the materials to be sampled in areas of low to medium relief would be residual soils and stream sediments. In areas of high relief only stream sediments would be collected. Most of the routine soil sampling was completed during the 1977/78 field season. Analysis of this material showed several areas to be anomalous in As, Cu, Pb, or Zn.

The first part of the 1978-79 field season was spent carrying out follow up work in the anomalous areas. Most anomalies were found to be associated with dolerite dykes. However, an area of anomalous arsenic values near Majors Creek remains unexplained, and additional sampling was carried out in this area.

The second part of the field season was spent collecting 300 stream sediment samples in the rugged coastal escarpment. Analytical work is well advanced.

ANALYTICAL LABORATORY, by B.I. Cruikshank

STAFF: B.I. Cruikshank, K.H. Ellingsen, G.R. Ewers, J.I. Fitzsimmons, C.R. Madden, J.G. Pyke, J.W. Sheraton, T.I. Slezak

During the year 3200 samples were handled in the laboratory. Of these, 2250 were analysed by quantitative methods (x-ray fluorescence and atomic absorption) for a total of 55 900 element determinations, and 950 by semi-quantitative emission spectroscopy for a total of 16 200 element estimations.

Projects receiving major laboratory support included:-

(1) the MAMMOTH MINES 1:100 000 Sheet area geochemical survey (1440 samples),
(2) the ARALUEN geochemical survey (445 samples),
(3) the McArthur River geochemical orientation survey (145 samples),
(4) the FORSAYTH geochemical survey (950 heavy-mineral samples by emission spectroscopy)

Highlights included the elimination of the long-lived backlog of samples for analysis, the completion of the new fumehood in the laboratory, and installation of a hydraulic rock splitter/crusher.

X-RAY FLUORESCENCE SPECTROMETRY

127 silicate samples, mostly from the Antarctic and Pine Creek projects, were analysed on the major element program.

Trace elements were determined on 2180 samples (33 500 element determinations).

ATOMIC ABSORPTION SPECTROPHOTOMETRY

2200 samples (21 100 element determinations) were analysed.

EMISSION SPECTROGRAPHY

950 heavy-mineral concentrates were analysed by semi-quantitative emission spectrography, each for 17 elements (16 200 element estimations).

MISCELLANEOUS

Sixty samples, from the Antarctic and Pine Creek projects, were analysed for FeO.

<u>IDC ON ENVIRONMENTAL QUALITY, WATER QUALITY SUB-COMMITTEE</u>, by A.D. Haldane

The sub-committee comprises representatives from the Departments of the Capital Territory, National Development, Construction, the Capital Territory Health Commission, National Capital Development Commission, and the Bureau of Mineral Resources, Geology and Geophysics and maintains close liaison with the NSW State Pollution Control Authority. The activities of the Sub-committee are primarily concerned with matters affecting water quality within the ACT but also recognise that adjoining areas of New South Wales may affect or be affected by water quality practices in the ACT. The main work during the year has been the formulation of a Water Pollution Ordinance which reached its final draft and has been submitted to the parent IDC. The Sub-committee is also concerned with a regional study of the Murrumbidgee River Basin and the results of other studies on Lake Ginninderra, Lake Burley Griffin and the Molonglo River, covering such factors as sewage and industrial effluents, urban run-off, and mine waste pollution.

INVESTIGATIONS OF THE ROLE OF PYRITE AND ETTRINGITE IN CONCRETE FAILURES IN THE ACT, by A.D. Haldane

A request was received from the Department of Construction for assistance with their investigation into the use of pyritic aggregate in concrete and its relation to concrete failure resulting from the formation of ettringite, a basic calcium aluminium sulphate.

A particular case was the dishing of paving flags at Parkes Place, ACT. BMR had previously advised the Department of Construction on the use of aggregate quarried from pyritic rocks in relation to the failure of bituminous concrete road paving and acidic leakage from Corin Dam. As aggregate from the quarry that had previously supplied material causing road pavement failures had been used in the concrete base slab at Parkes Place, it was thought that this might be the cause of the paving flag failures. The matter was investigated by CSIRO who concluded that the dishing of the paving flags was due to the formation of ettingite resulting from attack of the base of the flags by water-soluble sulphate derived from aggregate used in the concrete base slab. Investigations by BMR were unable to confirm this theory and instead suggest that although ettringite fills voids and fractures and could be the immediate sole cause of the dishing, the source of sulphate is the paving flats themselves. The flats had been made from an unusually cement-rich mix which was observed to have undergone extensive carbonation. As the sulphate level in the flags is not excessively high, the dishing could be due to a combination of bad concrete design, leaching, and carbonation, and the attendent crystallisation of ettingite in voids and fractures.

Although the precise mechanism of failure of the flags is not established it is evident that the failure cannot be related to the use of pyritic aggregate in the concrete of the supporting base slab.

GEOCHRONOLOGY LABORATORY

STAFF: L.P. Black, M.J. Bower, N.C. Hyett, R.W. Page, and T.K. Zapasnik

GENERAL

During the past year the Geochronology Group continued to apply successfully U-Pb zircon and Rb-Sr dating techniques on several important Branch projects in the Northern Territory, Queensland, Antarctica, Tasmania, and New South Wales. Two of the Group (Zapasnik and Hyett) functioned well in the sample preparation area, and finished 19 zircon separations, 30 total rocks and 6 mica separations. The remainder of the Group continued to use the joint Rb-Sr and U-Pb isotope laboratory facilities in the Research School of Earth Sciences, ANU. It is appropriate to acknowledge the continued cooperation and assistance from the Director and Staff of the School in other activities.

Part of the year was spent identifying and rectifying problems associated with the Rb-Sr laboratory. A colorimetric technique (using sodium rhodizonate), by which the ion-exchange columns could be precisely calibrated within a short time, was established. This revealed that the insensitivity in Sr runs resulted from a dirty mass-spectrometer source. Later, spiked Rb, was found to be originating from the ion-exchange columns, and was presumably part of a solid phase slowly moving through the resins. Many analyses, performed before this effect was detected, had to be repeated because both the Rb and Sr runs had been contaminated.

Black gave lectures on 'New Developments in Geochronology' in the BMR Tuesday lecture series and at the BMR Symposium. He delivered a talk entitled 'Preliminary isotopic ages from Enderby Land, Antarctica" at the Workshop on Antarctic Geology in Melbourne on May 17-18. Both Page and Black renewed their shotfirer's certificates with Telecom in Sydney.

Since July, Page has been co-supervising the work of a Chinese visitor to the ANU, Mr Liu Dun-yi. Mr Liu is working on a Chinese Archaean project, and is learning and using the U-Pb zircon method.

A 1200 Ma-old zircon from Arizona was recently prepared and distributed to some laboratories by workers at the California Institute of Technology. During the year several U-Pb isotopic analyses were made on the sample in this laboratory, with the aim of assessing its suitability as a future world-wide standard for zircon geochronology.

ALLIGATOR RIVERS PROJECT, by R.W. Page

The past 6-year program of Rb-Sr and K-Ar studies was this year extended by use of the U-Pb zircon approach on a number of samples from the East Alligator River area. All of the East Alligator geochronology results were delivered in a paper and written up in the Proceedings of the International Uranium Symposium on the Pine Creek Geosyncline. Salient points from the new zircon work and from the overall assessment of all the isotopic data are:

1. Granitic gneisses of the Nanambu Complex have U-Pb zircon and Rb-Sr total-rock ages in very good agreement at 2470 Ma, interpreted as the age of crystallisation.
2. Granitic rocks and granulites from the Nimbuwah Complex were formed at about 1860 to 1880 Ma ago. These results, together with previous Rb-Sr isotopic data, demonstrate beyond doubt that the Nimbuwah Complex rocks had had no prior crustal residence, and cannot have been derived by the reworking of earlier Archaean (Nanambu-type) gneisses or Lower Proterozoic schists.
3. The main regional metamorphism occurred about 1800 Ma ago, and several post-tectonic granites and dolerites have emplacement ages of 1730-1780 Ma and 1690 Ma, respectively.
4. The formation of retrograde chlorite-rich haloes in the vicinity of the uranium deposits, post-dates some of the intrusive rocks. In the vicinity of Nabarlek and Jabiluka, this metasomatic event has been dated at approximately 1600 Ma.

Field work conducted in the Pine Creek area in 1979 was aimed at (i) better refinement of U-Pb ages of emplacement of the Carpentarian granites, (ii) finding the U-Pb zircon age for the Edith River Volcanics, (iii) finding the age of the Lower Proterozoic Gerowie Tuff, and (iv) reconnaissance geochronological work in the Litchfield Complex, south of Darwin.

McARTHUR RIVER PROJECT, by R.W. Page

Two large (100-kg) samples of tuffaceous rocks were collected by C.E.C. geologists in 1978 from the McArthur exploratory adit prior to its flooding late that year. The aim of this project has been to find primary igneous zircon in the tuffs, and to see if we could then extend our earlier successful approach used to date the tuff marker beds from the Mount Isa Group.

One of the two McArthur tuffs yielded no zircon. The other, a tuff from the lower dolomitic shales below the HYC orebody, yielded a total of 5 mg of fine zircon, some of which has now been purified by extensive hand-picking under the microscope. Stubby, euhedral crystals, which appear to be of igneous derivation, form the bulk of the zircon population, and it is confidently expected that their age of crystallisation, approximating the age of deposition of the tuff, will soon be known.

MOUNT ISA PROJECT, by R.W. Page

The chronology of several Proterozoic volcanic and intrusive sequences in this area is continuing to be elucidated, primarily by means of detailed U-Pb zircon dating of geologically well-controlled samples. These results will enable us to clarify a number of currently contentious geological interpretations, and hence to quantify more precisely the overall evolution of this important Precambrian terrain.

An attempt was made to date a few milligrams of zircon extracted from a 300-kg sample of porphyritic basalt from the Eastern Creek Volcanics. The zircon fractions consisted of rather shapeless, angular grains, and the resultant analyses are more than 60 percent discordant. This makes it very difficult to assess a precise age for the Eastern Creek Volcanics. The scarcity and unusual anhedral morphology of the zircons present in this sample in fact suggest that they are possibly of xenocrystic origin.

No direct age is yet available for the Corella Formation, although sampling this year of newly recognised rhyolites interbedded with the Corella Formation sediments will permit such a measurement. At present, the best estimate of a minimum age for the Corella Formation is given by the intrusive Burstall Granite and intrusive rhyolite dykes associated with the Burstall Granite. U-Pb zircon data from two different Burstall Granite samples are in good agreement at between 1730 and 1750 Ma, and the rhyolitic dyke sample has a similar age of between 1720 and 1730 Ma. Zircon data from another microgranitic body intrusive into Corella Formation in the Tommy Creek area, indicate a much younger age of about 1650 Ma.

ARUNTA BLOCK, by I.P. Black

Thirty rocks and minerals, comprising gneiss and granite samples from widely scattered areas, were isotopically analysed for Rb and Sr. This has completed the backlog of Arunta analyses. Interpretation of the data has begun. Initial emphasis is being placed on the ages of metamorphism within the area. The information will be used to decide top priority sampling sites for the 1980 field season.

A paper is being prepared on the age of the Stuart Dykes in the southern part of the Arunta Block. These N-S striking sykes are significant in that they do not intrude the sedimens of the Amadeus Basin for which they provide a maximum age. This age, of about 900 Ma, is in agreement with the previous older limit placed on the Amadeus Basin by Marjoribanks & Black in the Ormiston area.

WESTERN TASMANIA, by I.P. Black

Several years ago, Rb-Sr total-rock work showed that the Mount Read Volcanics were deformed about 400 and 500 Ma ago. It was not possible to obtain emplacement ages from this technique. In the past year U-Pb zircon dating has begun in an attempt to derive these primary ages. The Lobster Creek Volcanics could not be satisfactorily dated by zircons: they yield an age even younger than that produced from Rb-Sr, presumably because of the dual problem of inherited Pb and recent Pb loss. Initial data on the Comstock Tuff and Darwin Granite are promising and indicate that these bodies crystallised in the Middle to Upper Cambrian.

GEORGETOWN INLIER, by I.P. Black

One hundred and twenty-two rocks and minerals were isotopically analysed for Rb and Sr during the year. Data are not yet complete but the results are apparently indicating an age spread of more than 1000 Ma for the supposedly Proterozoic granites. Indeed some of these may be Palaeozoic.

Rb-Sr work has been completed on the Barnard Metamorphics to the east of the inlier, and the results are currently being written up with T.H. Bell and M.J. Rubenach of James Cook University. The rocks were deposited and deformed four times in the Middle to Upper Palaeozoic. They are not Precambrian in age as has been previously suggested, although they do show some evidence of having been derived in part by weathering from the Precambrian Georgetown Inlier.

COBAR AREA, by I.P. Black

A small dating project, in collaboration with geologists from the NSW Geological Survey, was commenced by sampling in the Cobar area during July. The aim of this study, which is restricted to Rb-Sr work, is to determine the age of the main deformation in the area.

ENDERBY LAND, ANTARCTICA, by I.P. Black

Laboratory work has currently been restricted to rocks of the Napier Complex which are the oldest in the area. No precise ages have yet been determined by the Rb-Sr technique for rocks from restricted localities because of generally poor spreads in Rb-Sr ratio. However, analyses of isolated basic members of the Amundsen Dykes have yielded relatively precise ages, the oldest of which are about 2400 Ma. As these dykes are not folded they provide a younger limit for the latest deformation (D_3) in the Complex.

Transparent pinkish zircons from Mount Hardy and Mount Sones yield an age of about 2500 Ma which is considered to be that of D_3. Both these locations also contain distinctly different zircon grains which are dark brown, less rounded, and characterised by much higher U/Th ratios. These are interpreted as having grown during the second deformation (D_2). At Mount Hardy they yield the same age as the pink zircons, presumably because of a more intense episode during D_3 in this area. At Mount Sones these brown zircons yield a chord extending from a lower age of 2500 Ma to an estimated upper intercept at about 3050 Ma, which is taken as the age of D_2. Future work is aimed at seeing back through these deformations to the first deformation-metamorphic event to affect the area.

HERBERTON-MOUNT GARNET AREA, by I.P. Black

Work on samples from this area, which has extended over several years, is now complete. A manuscript on the origin of the extensive Upper Palaeozoic igneous rocks in this area is now in an advanced stage of preparation. The data reveal that the simplest models of magma genesis are not applicable to these rocks. It is possible that they are partly crustal, partly mantle in origin. An important part of the key to the origin of these rocks is the Claret Creek

Ring Complex which is geochemically distinct from the great bulk of the temporally related igneous rocks, but with which it shares common initial Sr and Pb isotopic ratios. The most satisfactory model to explain the features of the Upper Palaeozoic magmatism is that the rocks were derived from originally igneous rocks of roughly dioritic composition within the crust but that these source rocks were approximately isotopically homogenised over the scale of magma generation immediately prior to final magma genesis, probably by volatile outgassing from deeper levels.

INTERNATIONAL ACTIVITIES

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES - SUBCOMMISSION ON PRECAMBRIAN STRATIGRAPHY, by K.A. Plumb

Plumb attended the Fifth Meeting of the Subcommission on Precambrian Stratigraphy in Duluth, Minnesota, September 15-19, 1979, in his role as Titular Member for Australia. The meeting was preceded by a 10-day excursion through the Precambrian successions of Ontario, Wisconsin, and Minnesota.

Stratigraphic correlation charts of the Precambrian of Australia, prepared in conjunction with R.D. Gee of the Geological Survey of Western Australia and B.P. Thomson of the Geological Survey of South Australia, were presented to the meeting, and it is proposed to prepare these charts for publication in an Australian journal. Comparison of these charts with data presented from other continents emphasises the relative completeness of the Precambrian geological record in Australia, and the important contribution which Australia can make to Precambrian research.

Following its 1977 decision to place the Archaean-Proterozoic boundary at 2500 m.y., the Subcommission has now provisionally recommended a 3-fold subdivision of the Proterozoic, with boundaries at 900 m.y. and 1600 m.y.; a 4-fold subdivision, with a third boundary at about 2100 m.y., is still under consideration. A 3-fold subdivision of the Archaean, with boundaries at 2900 m.y. and 3500 m.y., has been suggested for consideration. Appropriate nomenclature for these units is still under consideration.

The Subcommission proposes to publish its decisions, and to invite criticism, comment, and suggestions from the geological community, before its next meeting in 1982. Plumb proposes to carry out a survey of Australian reaction to the proposals, through the Geological Society of Australia.

MISCELLANEOUS ACTIVITIES

PRECAMBRIAN REGIONAL GEOLOGY, by K.A. Plumb

During the year papers by Plumb on 'The Tectonic Evolution of Australia' and 'Structure and Tectonic Style of the Precambrian Shields and Platforms of Northern Australia', originating from Symposium 103.3 of the 25th IGC, were published by Earth-Science Reviews and Tectonophysics respectively.

A comprehensive and up-to-date review of 'The Proterozoic of Northern Australia' has been completed by K.A. Plumb, G.M. Derrick, R.S. Needham, & R.D. Shaw, and is to be published by Elsevier in a book entitled 'The Precambrian of the Southern Hemisphere' (D.H. Hunter, Editor).

Plumb has submitted papers on the late Proterozoic tillites of the Kimberley-Victoria River region and the Duchess area to IGCP Project 38, to be published by Cambridge University Press in 'Pre-Pleistocene Tillites: A Record of Earth's Glacial History' (M.J. Hambrey & W.B. Harland, Editors).

IRIAN JAYA GEOLOGICAL MAPPING PROJECT SECTION

Head: D.B. Dow

IRIAN JAYA GEOLOGICAL MAPPING PROJECT

by

D.B. Dow

INTRODUCTION

The Irian Jaya Geological Mapping Project, which is a Colombo Plan Aid Project carried out jointly with the Geological Research & Development Centre (GRDC) of Indonesia, has the task of making a geological and ground gravity and magnetic survey of the whole of Irian Jaya.

In October 1979 it completed its first year of full-scale operations, during which substantial progress was made. In addition to 2 1/2 months' field work done in the last quarter of 1978, a 6-month field season was undertaken in the last half of 1979; staffing is nearly complete and all but two of the eight Australian staff have taken up residence at the GRDC headquarters in Bandung, Indonesia; and all the necessary infrastructure, including an administrative unit and geological and geophysical offices in Bandung and a semi-permanent base camp at Nabire in Irian Jaya, have been set up. Most of the equipment needed, both at head office and in the field, including vehicles, river trucks, field equipment, geophysical and geological instruments, office equipment, and a Hewlett Packard Mini Computer with a wide range of peripherals, has been delivered to Indonesia.

FIELD CONDITIONS

Very few regions in the World pose greater problems for the field geoscientist than Irian Jaya. Except for a single road servicing the oil fields of Kepala Burung (The 'Bird's Head') and small road networks around each of the coastal towns, there are no roads, and all access is by boat to the coast and coastal swamps, and by aircraft to sporadic airstrips in the interior. The only practical method of completing the work within a reasonable period - the mapping and the reporting is scheduled to be completed within 10 years - is to use helicopters for access to all the field locations.

Field work during 1979 illustrates the great complexity of the operation. The geological and geophysical parties worked at different times from the major centres of Sorong, Manokwari, and Nabire, and from fly camps at

Ayawassi, Ransiki, and Wasior, and were supplied, depending on the circumstances, by helicopter, chartered fixed-wing aircraft, local coastal launches, powered canoes, and the Project's two river trucks. Had communica-tions between Jakarta and Irian Jaya been reliable the logistics of the operation would have been daunting enough, but due to bad weather, mechanical breakdowns, and other causes, the regular air services from Jakarta to the main centre of operations, Manokwari, commonly fail for several days on end, upsetting carefully planned field schedules.

Other challenges to an orderly program in 1979 included an isolated incident of sabotage which resulted in one helicopter being out of action for over a week, and a helicopter crash in early October which interrupted operations for nearly two weeks. By great good fortune nobody was hurt in the crash, but in the subsequent fire the helicopter and valuable geophysical instruments were destroyed.

The field method used by geologists involves the transporting by helicopter of traverse parties to a field location for traverses of one to eight days duration. Generally outcrops are found only along rivers so the geologist spends most of his time wading and climbing around gorges and waterfalls; this work is relieved only by the crossing of jungle-covered mountains from one river to another.

The geophysical work is scheduled each year for 5 to 6 weeks in the middle of the helicopter contract in September and early October. In the early stages of the Project the geophysical parties are able to operate out of the same camps as the geologists, but because of the disparate rates of progress this will not always be possible.

Gravity and total-magnetic field readings are taken on the ground on a 10-km-square grid where helicopter landing sites allow. In some areas of sparse landing sites the grid is distorted, and in some areas such as the Arfak Mountains, some readings have to be missed entirely.

MAPPING PROGRESS

Full-scale geological mapping commenced in Kepala Burung in October 1978 and the mapping completed to mid-August (to the start of the Lebaran field break) is shown in Figure J1. The work includes a systematic geochemical stream sampling program in which both panned and minus-80 mesh samples are taken during the geological traverses. A density of one sample to each 10-20 km^2 drainage

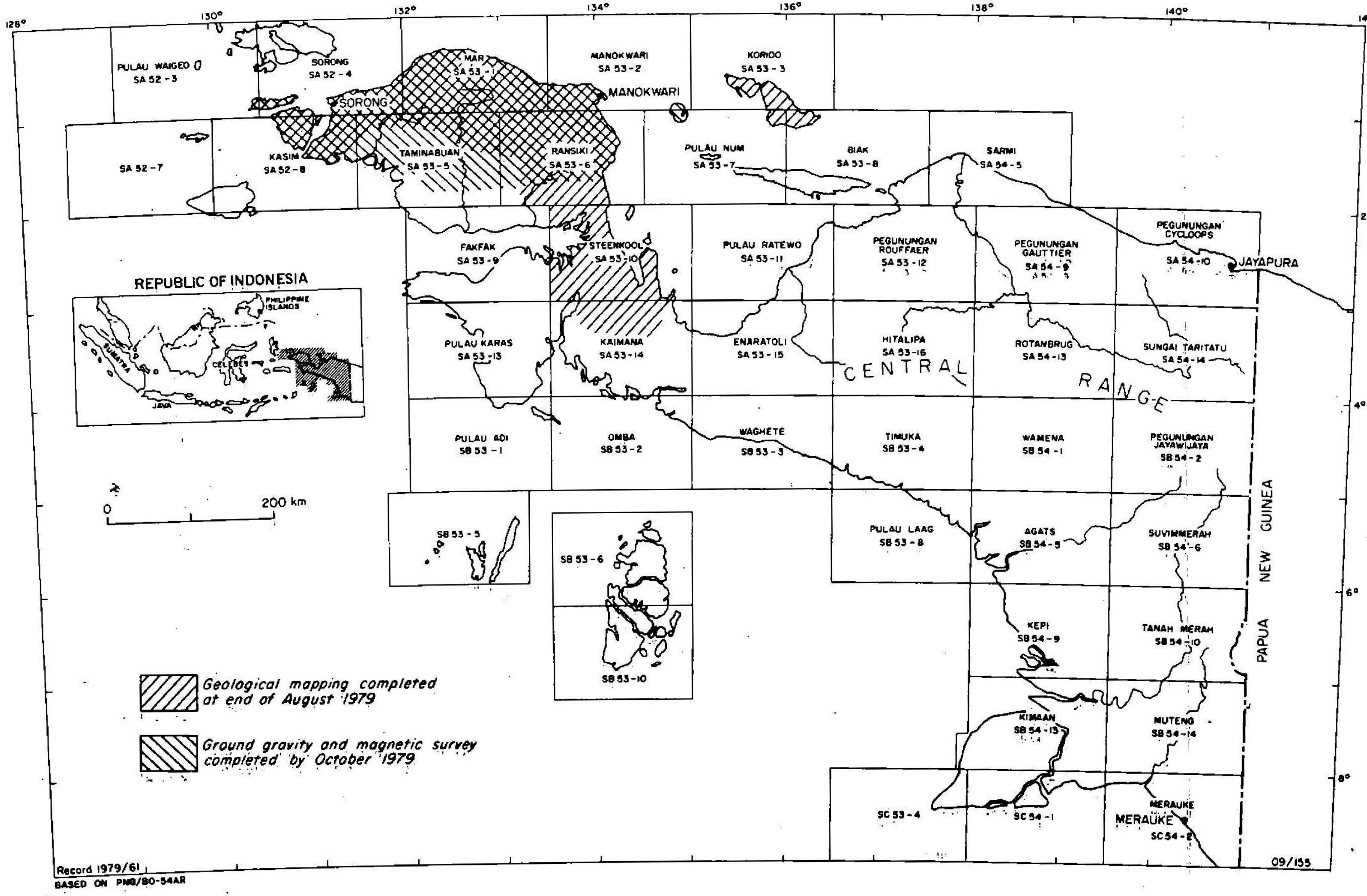


Fig. J1 Locality map, Irian Jaya mapping project basin is aimed at, though in areas of difficult access such as the Arfak Mountains, the density is much less. Progress made with the geophysical survey during the first field season between 1 September and 8 October is also shown in Figure J1.

The Project work also includes a palaeomagnetic sampling program in Kepala Burung to help elucidate the post-Carboniferous plate movements in the region. The study of macrofossils is an important part of the geological work and the Project is setting up a Macropalaeentology Research Unit in the Geological Survey of Indonesia to carry out this work.

In view of the problems mentioned earlier, and of the need to train our Indonesian counterparts, remarkable progress has been made and the survey work is well up with the aim of completing the field work within seven years.

Because of the late start to the field work in 1978 and the time spent in early 1979 transferring to, and setting up office in, Bandung, and as a result of the multifarious tasks involved in setting up the Projecc from scratch, plus the preparations needed for the 1979 field season, it proved possible to schedule only two months to compile the huge amount of data accumulated during the 1978 field season. The schedule of compilation and report writing is therefore not as satisfactory as the field schedule, though it is hoped to catch up with some of the backlog in early 1980.

GEOLOGY (Fig. J2)

The broad outline of the stratigraphy of Kepala Burung as given by Visser & Hermes (1964) has stood up well to the more detailed mapping done by the Project. The most important advances resulting from the mapping include:-

(a) The confirmation of Palaeozoic metamorphics and granite north of the east-west Sorong Fault Zone in the northern extremity of Kepala Burung, shows unequivocally that a fragment of Australian continental crust is present north of the Fault Zone.

(b) The discovery of a 1000-m-thick slab of intermediate to acid volcanics and volcanigenic sediments of Middle Miocene age (Moon Volcanics) overlying the Palaeozoic continental crustal rocks. These volcanics north of the Sorong Fault Zone are in marked contrast to the rocks of the same age overlying the basement to the south which are entirely shelf limestone and fine calcareous sediments. No trace of volcanics has been found in the southern sediments.

(c) The presence of a major crustal discontinuity north of the Sorong Fault Zone, the east-west Koor Fault Zone, which separates the continental fragment north of the Sorong Fault Zone from Eocene to Oligocene volcanics with oceanic affinities which make up the extreme northern 'cap' of the 'Bird's Head'. The Koor Fault Zone could be the plate boundary separating the Pacific Plate from the fragment of Australian Plate which underlies the whole of the 'Bird's Head' and 'neck'.

(d) Isotopic age determinations made on the granite intruding the Palaeozoic metamorphics which give ages ranging from Devonian to Permian. A pebble of granite from Carboniferous sediments overlying the basement metamorphics gave a Precambrian age, indicating an older provenance in the region.

(e) Copper, lead, and zinc mineralisation has been found in the Middle Miocene Moon Volcanics and though the geochemical results from streams draining the Volcanics were disappointing, the region could be one of considerable economic potential.

(f) The geochemical results also showed fairly widespread anomalous tin and tungsten in panned samples from streams draining high-grade Palaeozoic metamorphics intruded by granites. Traces of gold were also detected in panned samples in many of the streams draining these rocks and also the Moon Volcanics.

GEOPHYSICS

Gravity and magnetic coverage was obtained over 80 percent of Kepala Burung during a brief reconnaissance in 1978 and a 6-week survey during 1979. Apart from a few isolated gravity observations, there were no previous geophysical data for the main part of Kepala Burung. Visser & Hermes (1964) show abundant gravity coverage over the Salawati Basin (westernmost part of Kepala Burung) and over the swamps around Bintuni Bay, south of the survey area. Those data are not available in Indonesia and will be sought in Holland.

Operational problems and inadequate staffing did not allow concurrent calculation of results to be maintained during the 1979 season, but the main features of the Bouguer anomaly field are:

(a) A gravity low of about zero milligals over the karst country of central Kepala Burung.

(b) A complex gravity gradient trending east-west across the northern part of Kepala Burung, with positive anomalies up to a maximum of +171 mGal. north of the gradient, which is clearly associated with the Sorong Fault Zone. The gradient is very steep across the northern part of Salawati Island in the west and is moderately steep north of Manokwari in the east. In between, the gradient is less steep but greater in overall amplitude across the Sorong Fault Zone and the parallel Koor Fault Zone. Gravity does not clearly define any particular position for a single major discontinuity between continental and oceanic crusts, and the zone is undoubtedly complex and varies structurally along its length.

(c) A north-northwest-trending gravity gradient associated with the Ransiki Fault in eastern Kepala Burung. Results from the islands Numfoor and Num further to the east will show whether the Sorong Fault Zone is significantly offset by the Ransiki Fault.

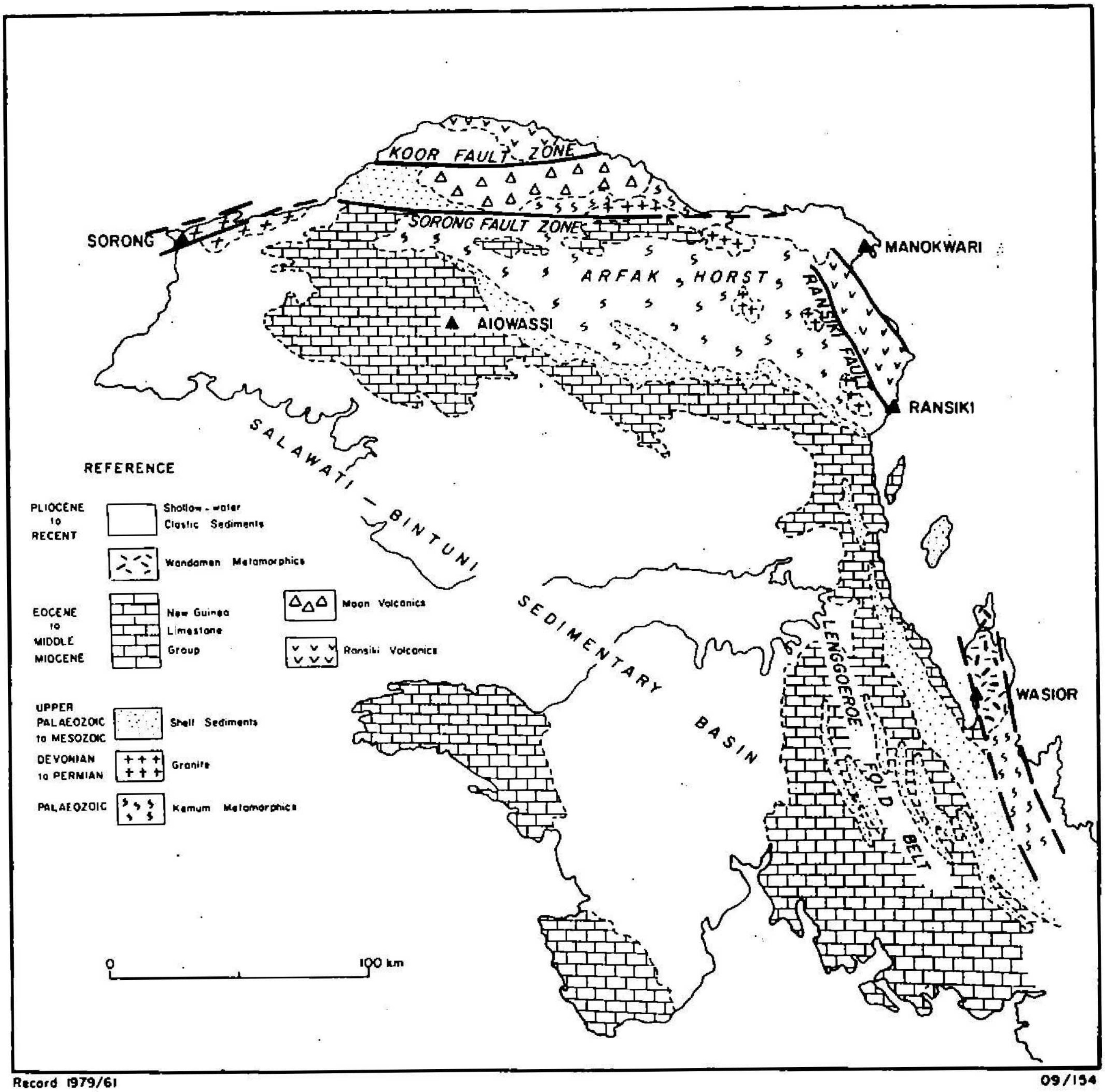


Fig. J2 Geological sketch map, Kepala Burung, Irian Jaya

GEOLOGICAL SERVICES SECTION

Head: E.K. Carter

INTRODUCTION

The continued subdued growth of Canberra and the decision to restrict ad hoc services led to a further decline in client-requested activities in the A.C.T. The Engineering Geology and Hydrology Sub-section is currently not involved in any major construction activity in the A.C.T. apart from the completion of reports. Data-gathering, several problem-solving and research projects, and the preparation of special-purpose maps, are continuing. The Sub-section is providing supervisory services during the construction of the Telecom cable tunnels in Melbourne; construction started in early October. New projects started during the year include an evaluation of groundwater on Niue Island, South Pacific, and location of a supply of water for irrigation (completed); and a study of the hydrogeology of the superficial cover in areas of the Alligator Rivers Region, N.T., adjoining uranium mining areas (continuing).

The main compilation effort by the Map Editing and Compilation Group (including the writing of commentaries) was directed towards the BMR Earth Science Atlas of Austrlia, several maps and notes for which are now (end October) with the printer. Work was done on several other maps.

A computer-based system for the Stratigraphic Index was developed during the year and all input and output related to current literature is now computerised.

The main research activity by Museum staff was the field and laboratory study of the first significant Australian discovery of commercial quality ruby: in the Harts Range, Central Australia. Displays were provided for five inter-state and local exhibitions.

The Section Head dealt with stratigraphic nomenclature matters and maintained (with others) an awareness of the state of the technology for the disposal of radioactive waste. He visited the Alligator Rivers region and took part in a field review of the geology of parts of the Mount Isa-Cloncurry region.

ENGINEERING GEOLOGY AND HYDROGEOLOGY

STAFF: E.G. Wilson, G. Jacobson, D.C. Purcell, G.A.M. Henderson, P.H. Vanden Broek, W.R. Evans, J.R. Kellett
Technical Officers: G. Sparksman, B. Jones
Technical Assistants: A.W. Schuett, D. Guy
Field Assistant: R. McPake

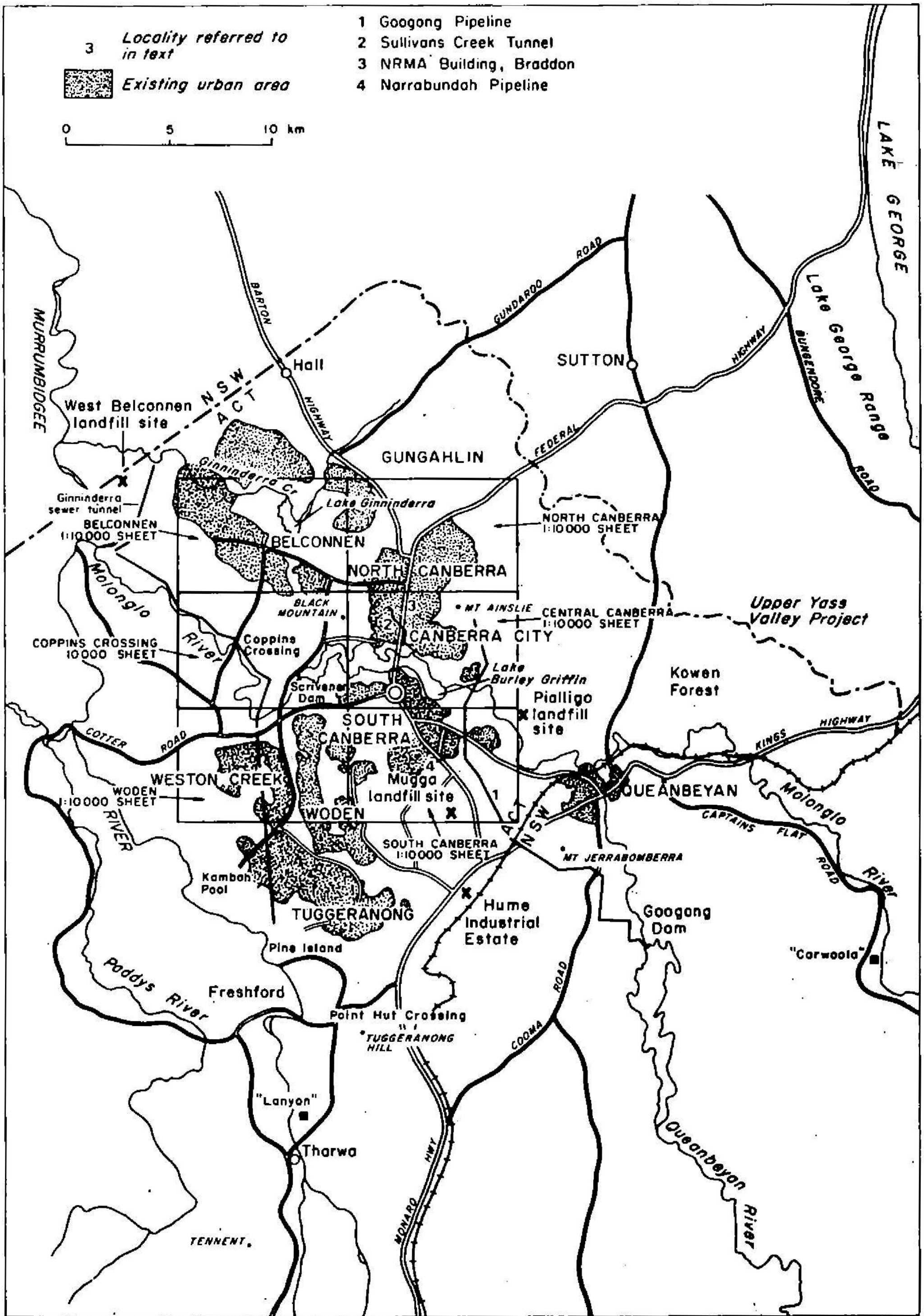
GENERAL

by

E.G. Wilson

Investigations and research projects in engineering geology and hydrogeology continued. Clients and collaborators included the Department of Housing and Construction, National Capital Development Commission, Department of Capital Territory, Department of Science and Environment, Australian Development Assistance Bureau, and CSIRO Division of Land Use Research. Compared with previous years, fewer investigations related to Canberra's development were undertaken, because of the continued slowdown in growth of the national capital. Work proceeded on the compilation of a series of 1:10 000 engineering geology maps of the Australian Capital Territory. The locations of projects in the A.C.T. reported below are shown in Fig. G1. An engineering geological investigation was also undertaken for a Commonwealth government tunnel in Melbourne.

Water is an important mineral resource, especially in Australia, and in keeping with the changing role of BMR towards 'scientific understanding of the geology ... as a basis for ... mineral resource assessment, exploration, development, and production' several groundwater research projects are being developed by the group. These include catchment modelling, hydrochemical and groundwater pollution studies in the ACT and Northern Territory, and compilation of a hydrogeological map of the ACT. Groundwater resource investigations were also undertaken for the Australian foreign aid program on Niue Island in the South Pacific, and in Sumatra, Indonesia (the latter by review of consultants' work only).



Record 1979/61 I55/A16/2175-1

Fig. G1 Engineering geology and hydrology; locations of projects, Canberra and adjacent areas, 1979

ENGINEERING GEOLOGY FOR CANBERRA DEVELOPMENT

by

P.H. Vanden Broek, D.C. Purcell, W.R. Evans, and E.G. Wilson

Engineering geology services for the planning, investigation, design, and construction of Canberra's development works were provided for the Department of Housing & Construction, and the National Capital Development Commission (N.C.D.C.).

GOOGONG DAM SPILLWAY CHANNEL by D.C. Purcell

The Googong Dam spillway channel was inspected in company with engineers from the Department of Housing & Construction and a consulting engineer. The purpose was to examine the effects of erosion on the floor of the rock channel caused by continuous discharge from the dam since June 1978. The area of spillway channel that had been eroded was then mapped, and the severity of erosion indicated. An assessment was made of the future erosion potential of the various rocks downstream of the concrete toe of the spillway, based on degree of weathering, and distribution and condition of defects. Remedial treatment was later undertaken by the Department of Housing and Construction.

GINNINDERRA SEWER TUNNEL by P.H. Vanden Broek

The project was described in the Branch's Annual Summary of Activities for 1977; its purpose is to link the Belconnen sewerage system to the lower Molonglo Water Quality Control Centre. Tunnel excavations were completed by September, 1978 and concrete lining began immediately. The contract was completed in September 1979 and the tunnel was brought into service a few days after work was completed. Geological services were provided as required during the lining operation.

A completion report which compares actual to predicted conditions, and gives excavation rates, overbreak, and support requirements, is being written.

Fourteen percent of the tunnel required support; an average excavation rate of 11.4 m/day was achieved, and the average overbreak was 44.5 percent outside the pay line.

SULLIVANS CREEK SEWER TUNNEL by P.H. Vanden Broek

The project was described in the Branch's Annual Summary for 1978; its purpose is to link the central city sewerage system to the Commonwealth Avenue Bridge pumping station, and thereby augment the capacity of the system, which is overtaxed by sustained heavy rainfall.

The design report for the tunnel was completed and several minor changes to the tunnel route were discussed with N.C.D.C. and their engineering consultants.

REGIONAL SAND AND GRAVEL SURVEY by P.H. Vanden Broek

The project was described in the Branch's Annual Summary for 1977; the survey was to look at all aspects of sand and gravel supply to Canberra at the request of N.C.D.C.

The study concluded there is sufficient sand available at presently economic haulage distances to supply Canberra's requirements beyond the year 2000.

NARRABUNDAH WATER SUPPLY PIPELINE by W.R. Evans

A water supply pipeline route from Mugga Reservoir to Narrabundah was geologically mapped, and a seismic survey was done by the Engineering Geophysics Group. The route is in colluvial deposits for 85 percent of its length, and bedrock consists of Mount Painter Volcanics, with rhyolite dykes, stratigraphically overlain by bedded rhyolite and Mugga Porphyry. An assessmnt of excavation conditions was made for the Department of Housing & Construction.

A.C.T. ROAD PAVEMENT INVESTIGATION by E.G. Wilson

The Department of Housing & Construction is investigating the durability of road pavements in the A.C.T.; a number of pavement failures have occurred. About 30 locations were inspected and information concerning geology, soils, and groundwater conditions was recorded. Low-permeability clay soils with large shrinkage cracks are common to many sites, and the cracks have been enlarged by infiltration of rainwater, and possibly by the removal of dispersive clay minerals.

ENGINEERING GEOLOGY AND SPECIAL MAPS OF CANBERRA

by

G.A.M. Henderson

1:10 000 ENGINEERING GEOLOGY MAPS

Work continued on the gathering of data for, and the preparation of, the first six maps in the 1:10 000 Engineering Geology series maps of Canberra. Drilling in the north Canberra area revealed deep weathering in several places, and two holes at Dickson passed through 43 m of clay, with iron and manganese mineralisation, into limestone. A hole was drilled to 30 m in the Narrabundah Ashstone near Jerrabomberra Creek without reaching the base of the unit.

Close liaison was maintained with Coffey & Partners, who carried out investigations at the new Parliament House site on Capital Hill; geological information was made available and discussions on the ground conditions and structure at the site were helpful.

Additional data in the South Canberra area were derived from the mapping of excavations for a water pipeline linking the Googong Pipeline with Red Hill reservoir.

The current (October 1979) state of progress of the six maps is as follows:

Coppins Crossing	- map being fair drawn under contract.
Central Canberra	- map compilation and notes complete, editing in progress.
Belconnen	- map compilation drawn, explanatory table and notes in preparation.
Woden/Weston Creek	- map compilation drawn, explanatory tables and notes in preparation.
North Canberra	- map compilation at an advanced stage.
South Canberra	- map compilation in progress.

1:50 000 CANBERRA AND QUEANBEYAN GEOLOGICAL MAP

Additional information from mapping in the Lanyon area by J.R. Kellett was added to the map compilation, and the map has since been edited for publication.

HYDROGEOLOGICAL MAP OF THE A.C.T. AND ENVIRONS

Work continued on the compilation of groundwater bore data for the preparation of a hydrogeological map of the A.C.T. and environs at 1:100 000 scale.

ENGINEERING GEOLOGY OF TELECOM TUNNELS, MELBOURNE

by

E.G. Wilson

The Telecom tunnels comprise 1881 m of cable tunnel and connecting chambers beneath Queen, Lonsdale, Russell, Exhibition, and Rathdowne Streets in central Melbourne. The geological investigation for tunnel design (by Department of Housing and Construction engineers) was reported in BMR Records 1978/16 and 1978/90.

Five shafts of 1 m diameter were drilled in January 1979 to about 1 m below invert level at location, four of which were offset from the line of the tunnel. The shafts were logged, and supported to allow for inspection by tenderers for the tunnel construction contracts.

The contract was let to Cadelfa-Cogefori Construction Pty Ltd; tunnelling commenced early in October, and will continue for 45 weeks. The Project Geologist provided by the Department of Housing and Construction is being supervised by the Engineering Geology group.

GROUNDWATER POLLUTION INVESTIGATIONS, A.C.T.

by

G. Jacobson

Several groundwater pollution investigations were undertaken in the Australian Capital Territory on behalf of the Department of the Capital Territory and the National Capital Development Commission.

Pollution of groundwater by petrol that has leaked from underground installations has occurred in recent years at two locations in Canberra. A remedial pumping scheme has been installed at one of these sites - the Center Cinema in Canberra City - and some petrol has been recovered from a skimming well situated in the centre of a cone of depression induced by pumping from a deep bore. Monitoring of this scheme continued throughout the year. At a second location - the NRMA Building in Braddon - six drillholes outlined a pollution plume of petrol floating on the watertable, and probably emanating from the building's own underground petrol tank. Rises in the water table have carried petrol into the foundation drains of the building. Monitoring is continuing while possible remedial schemes are assessed.

Investigation of groundwater pollution from leaked industrial effluent was undertaken at the Hume Industrial Estate. Groundwater from several bores in alluvial sand aquifers was found to have a high content of dissolved organic carbon and phenols. The bores outlined a groundwater pollution plume extending one kilometre from a timber mill; the pollution was possibly caused by overflow from effluent ponds.

Monitoring continued at two operating sanitary landfill sites - West Belconnen and Mugga Lane - to assess the effect on the surrounding groundwater of leachate developed in the landfill. A third site at Pialligo closed in 1978 and continued monitoring there has indicated some pollution of groundwater by leachate generated in the landfill.

ALLIGATOR RIVERS HYDROGEOLOGY STUDY, N.T.

by

J.R. Kellett

BMR was invited by the Office of the Supervising Scientist to participate in a joint Northern Territory-Commonwealth government study of the hydrogeology and hydrochemistry of the Magela and Cooper Creek catchments. A mass transport model is to be developed for groundwater management in the uranium mining areas of the Alligator Rivers region.

A field party was based at Jabiru from July to November to gather as much baseline data as possible before any impact from mining becomes apparent in the environment. Contract drilling and installation of monitoring bores was supervised at Nabarlek and in the Magela valley. All bores were constructed with stainless steel screens and unplasticised pvc casing and then developed for pump testing and chemical analysis of the groundwater. Sampling for groundwater chemistry in these bores and in some springs is intended to be done at the end of this dry season and thence at quarterly intervals.

Infiltration tests were done on each major soil group mapped by N.T. Soil Conservation Unit in both catchments. Saturated hydraulic conductivities of the black cracking clays which occur extensively over the Magela floodplain from Long Island to Nankeen billabong, range from 1 mm/hr at field capacity to over 13 mm/hr at 45% antecedent moisture content. Infiltration capacities of the gleyed saline cracking clays from Nankeen billabong to the Magela breakout range from 0.2 mm/hr near field capacity to an indeterminable rate at about 50% antecedent moisture content. The red and yellow massive earths which cover most of the older lateritised land surfaces of the southern Magela catchment and the Cooper Creek catchment range from 1 mm/hr at field capacity to over 30 mm/hr at 10% antecedent moisture content.

GROUNDWATER AND LAKES, N.S.W. AND A.C.T.

by

G. Jacobson

Monthly monitoring of Lake George, N.S.W., water levels continued. A water balance for the lake has been derived, based on 20 years' data, and a paper on this was published in the BMR Journal. Stream flow data from the Water Resources Commission of NSW is being incorporated in the water balance model.

In the Federal Territory of Jervis Bay, monitoring of water levels in Lake Windermere and 17 bores continued. Data are being accumulated for use in a lake water balance model. The general water level has dropped from the historic high levels of two years ago; for instance, in sand areas that were then water-logged and swampy the general water table level is 1 m below surface (October 1979).

UPPER YASS CATCHMENT STUDY, N.S.W.

by

W.R. Evans

The group is undertaking, jointly with CSIRO, a study of the upper Yass River valley catchment which has been designated a Representative Basin by the Austrlian Water Resources Council. The work is aimed at defining the subsurface component of the basin's hydrology. Work commenced in 1978 and was reported in the Geological Branch Summary of Activities, 1978.

Contract drilling in February 1979 completed the drilling program for the identification of major and minor aquifer systems. About 10 deep holes and 50 shallow holes for piezometers, make up the monitoring network. The drilling established the locations of old stream gravels, comprising fragments of weathered siltstone and sandstone, at several levels within the depositional profile. Further study will determine the relative ages of these gravels one to another, as they occur within the higher geomorphic levels of the landscape, and are probably remnants of the oldest superficial deposits in the area.

A small catchment within the basin was studied in detail during August 1978 to investigate the movements of major nutrients, and the data were later analysed at Division of Land Use Research, CSIRO, by Dr B. Williams. The results were presented as a discussion paper titled 'The hydrochemistry of an aquifer network' at an agricultural conference in New Zealand in March 1979. The aim of the study was to determine the best method for characterising water chemistry at a point, and then use those characteristics to determine mixing and the preferred pathways for movement of waters.

HYDROGEOLOGY OF NIUE ISLAND

by

G. Jacobson

On behalf of the Australian Development Assistance Bureau, an investigation of the groundwater resources of Niue Island was undertaken between 30 March and 11 May, 1979. The BMR team consisted of G. Jacobson (geologist), P.J. Hill (geophysicist), and A.W. Schuett (groundwater technician).

Niue Island is in the south Pacific Ocean at approximately 19°05'S, 169°50'W. The island is about 20 km long and 15 km wide, and is a raised coral atoll developed on top of a volcanic seamount.

The original atoll form of outer rim (elevation 60 m) and inner lagoon (elevation 35 m) is well preserved. More than 200 m of coral limestone of Miocene age has been cored in four mineral exploration drill holes without reaching the underlying volcanic rock.

The field investigation included inspections of geological features such as caves and springs; a data census of existing water bores on the island; gravity and magnetic surveys to determine the depth to sub-limestone basement; electrical resistivity surveys to determine the thickness of the freshwater layer; contract drilling and construction of two water production bores and two observation bores; aquifer testing; measurement of tidal response in bores; and water sampling for electrical conductivity measurement and chemical analysis.

There is no surface drainage on Niue. The mean annual rainfall is about 2000 mm, of which an estimated 1400 mm is lost in evapotranspiration; the remaining 600 mm infiltrates to the water table.

Groundwater is contained in a freshwater layer overlying salt water. The maximum elevation of the water table is 1.8 m above sea level and fresh water flows radially outwards to the sea (Fig. G2). Salt water intrusion is evident for 500 m inland from the coast, where mixing has been facilitated by fissures in the limestone.

The thickness of the freshwater layer was determined by electrical resistivity depth probes. Preliminary calculations show that the freshwater layer is 60-70 m thick in the centre of the island, increasing to 100-150 m at 1-2 km inland from the coast, then decreasing to 0 within 500 m of the coast.

Drilling at two test sites was undertaken, with construction of a production bore and observation bore at each site. Aquifer tests showed the following yield-drawdown relationship:

	Yield (l/s)	Drawdown (m)	Specific capacity (l/s/m)
Production Bore (PB) 1	3.82	2.10	1.82
Production Bore (PB) 2	3.54	0.28	12.64

The specific capacity is given in litres/second/metre of drawdown. It is an index of the productivity of the bore and is related partly to permeability and partly to efficient bore construction.

For purposes of computation a freshwater-layer thickness of 72 m has been assumed over most of the interior of Niue. Assuming that it will be safe in the long term to reduce the freshwater layer thickness by half (36 m) and lower the upper surface of the lens by about 1 m, then the amount of groundwater available for extraction is about 1200 l/day/ha, allowing for the most severe historical drought in the Niue meterological records. The safe long-term pumping rates have been calculated as 1.64 l/s for PB1 and 7.98 l/s for PB2.

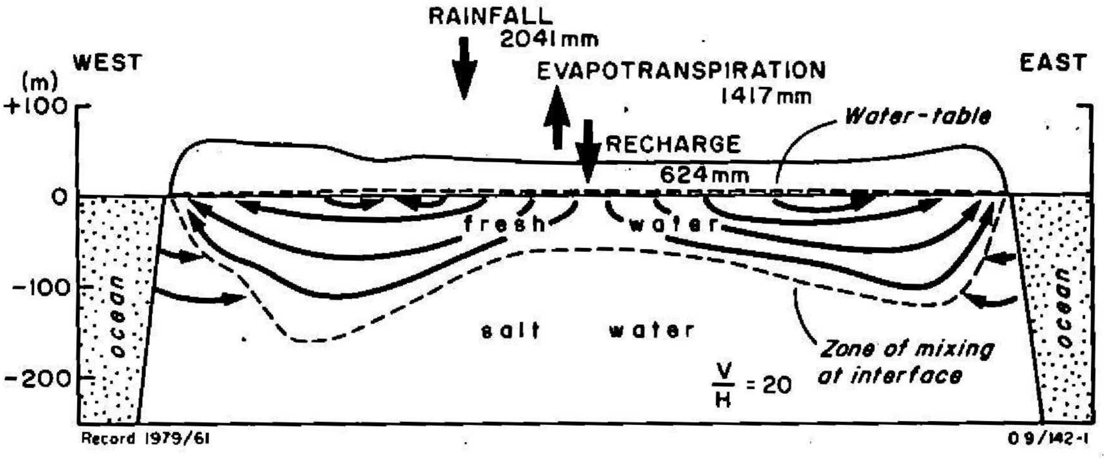


Fig. G2 Niue Island, South Pacific. Diagrammatic cross-section showing groundwater flow in the freshwater lens

At these pumping rates the area of land required to recharge the bores would be 12 ha for PB1 and 58 ha for PB2.

Recommendations for future groundwater development on Niue include the purchase of a rig capable of drilling bores with 12.5-15 cm casing. Casing is essential to protect pumps and should be perforated below the water table. The use of turbine pumps with capacity 1.5-2.5 l/s has been recommended, with the pump intake set at a level that will ensure a drawdown of not more than one-half of the water table elevation above mean sea level.

Water quality is expected to be suitable for most agricultural and urban uses. The electrical conductivity of groundwater samples in the interior of Niue is about 400 microsiemens/cm, equivalent to a salt content of about 250 ppm.

WATER SUPPLY INVESTIGATIONS, SOUTH SUMATRA

by

G. Jacobson

On behalf of the Department of Housing and Construction and the Australian Development Assistance Bureau, geological aspects of water supply investigations in South Sumatra were reviewed in December 1978.

At the town of Kota Bumi in Lampung Province, groundwater investigations to establish a town water supply have been undertaken by consultants. A well field with four bores producing a total of 70 l/s has been constructed a few kilometres from the town. The groundwater aquifers are in sandstone of the Upper Miocene-Pliocene Palembang Formation, and occur at depths of 60-100 m. An inspection was carried out in the initial stages of the production well drilling; since then the project has been satisfactorily completed. An assessment was also made of possible sources of construction materials for the water supply system.

At Tanjung Karang, the provincial capital of Lampung, groundwater resources within 30 km are insufficient for the development of a major town supply, although a well field could possibly be located in an area 40 km east of the town. The town water supply, which is currently derived from springs and stream, will be augmented by an expansion of this source. An appraisal was made of potential sources of construction materials for the project.

MAP EDITING & COMPILATION

by

W.D. Palfreyman

STAFF: G.W. D'Addario, W.D. Palfreyman, P.D. Hohnen, J.E. Mitchell, J.M. Bultitude (to 3rd April), A. Mikolajczak, R. Chan (from 4th April).

Advice was given when requested to authors and draftsmen on aspects of map compilation, especially map references and map symbolisation. Map Committee meetings, which review priorities and progress of the map publication program, were held on 21 November and 29 May. The booklet, 'Symbols used on geological maps' was printed and distributed to all BMR geologists and draftsmen.

D'Addario completed draft texts to accompany the BMR Atlas maps Cainozoic Thickness & Weathering and (with H.A. Jones) Surface Drainage & Continental Margins. A commentary for the Main Rock Types map for the BMR Earth Science Atlas of Australia is being written and commentaries have been written for the General Geology and Main Structural Elements maps. Four maps and accompanying commentaries have been produced by the Geophysical Branch. It is hoped to have 10 maps and 6 commentaries for the Atlas printed by the end of 1979.

MAP EDITING

Fourteen maps were edited:

1:250 000 Geological Series	- Kikori, Derby, Noonkanbah.
1:100 000 Geological Series	- Hedleys Creek, Seigal, Cahill, East Alligator
Special Maps	- Pine Creek 1:500 000, Burdekin River 1:500 000, Wiso Basin 1:1 000 000.
1:10 000 Engineering Geology	- Coppins Crossing
BMR Earth Science Atlas	- Earthquakes, Plate Tectonics, Sedimentary Sequences

MAP COMPILATION

BMR EARTH SCIENCE ATLAS OF AUSTRALIA

Most of the maps in this series are at 1:10 000 scale.

Geology-Australia (G.W. D'Addario, W.D. Palfreyman, J.M. Bultitude).
The map was edited and fair-drawn.

Solid Geology-Australia (G.W. D'Addario, W.D. Palfreyman, J.M. Bultitude).
The map was edited and fair-drawn.

Some work was done on compiling a metamorphic map of Australia, and other BMR groups are producing a sedimentary sequences map of Australia and a coal map of Australia.

ATLAS OF AUSTRALIAN RESOURCES, 3rd SERIES - for Division of National Mapping

Geology of Australia, 1:5 000 000 (G.W. D'Addario, W.D. Palfreyman, J.M. Bultitude, R. Chan).
Compilation of the map and reference was completed.

COMMISSION FOR THE GEOLOGICAL MAP OF THE WORLD

Metamorphic Map of Australia, 1:5 000 000 (T.G. Vallance, University of Sydney).
A final compilation of the map and reference was received from Professor Vallance. This incorporates all contributions from BMR and State Surveys. The compilation is being checked. Final editing, and subsequent fair-darwing, await receipt of the accompanying commentary.

INDEXES, TECHNICAL FILES AND MINERAL REPORTS

by

K. Modrak and P.J. Kennewell

STAFF: K. Modrak, L. Kay, B. Jones (ceased duties with section 15 December), M. Amar (part time February), I. Zeilinger (part time from August 20), J. Morrissey (part time from August 30), P.J. Kennewell.

STRATIGRAPHIC INDEX

Literature on Australian geology received through BMR Library was indexed under the headings - stratigraphic name, author, 1:250 000 sheet area, basin name, and subject. From May 1979 the headings - structural province, detailed location, and 1:100 000 sheet area were added. From January, 1980 the various index cards previously sent to the Bureau library, BMR Basin Study Group, and State Geological Surveys (last sent in December 1978) will be replaced by computer printouts.

Computerisation of the Stratigraphic Index was started early in 1979. Sufficient development and testing had been carried out by late April 1979 to allow regular input to commence. Current literature indexed is put into the computer data base, GEODEX, from data sheets via a terminal.

New stratigraphic names were added to the Central Register of Stratigraphic Names and Definitions, and all references to these and previously published names were added to the card index, in a modified form from May 1979. Some 353 new names, 162 of which were previously reserved, and 83 definitions of units, were indexed in the period 1st October 1978 to 30th September 1979. In the same period 165 new names were reserved for use and 112 definition cards, submitted by authors through Divisional Stratigraphic Nomenclature Subcommittees of the Geological Society of Australia, were filed.

Six bi-monthly Variations lists (Nos 30-35) and one annual Deletions list (No. 6), noting additions to and deletions from the Central Register, were compiled and distributed to Stratigraphic Nomenclature Subcommittees, to State Geological Surveys, to Universities, and to mineral exploration companies. List No. 35 for the period July-August was partly compiled using the computer data base.

A progress report was circulated on 28 August to all State Surveys detailing the computerisation of the Index and requesting output requirements from the data base.

Inquiries and visits from authors, State Survey officers, and others regarding stratigraphic names, definitions, and literature references were handled.

Statistical information on the operations of the Stratigraphic Index was collated and sent to Mr H.R.E. Staines, Convener for the Stratigraphic Nomenclature Committee, for presentation at the committee meeting to be held in January 1980.

TECHNICAL FILES

Technical Files are on a care-and-maintenance basis.

MINERAL REPORTS

FLUORITE GEOLOGY PROJECT

All published literature on Australian fluorite deposits has been summarised onto a series of index cards, and has been supplemented by the purchase of the Field and Technical Surveys' data file on fluorite deposits, which includes summaries of unpublished open-file company reports held by State Mines Departments. Each deposit is being examined in its regional context to determine the probable source of the fluorine, and to develop an understanding of fluorine mineralisation throughout each structural province. A special study was made of the Georgina Basin. The results are being summarised into a Mineral Resources Report.

Concurrently, a literature review of the geology and geochemistry of fluorine is being carried out to determine factors responsible for the world's larger fluorite provinces. The conclusions will be applied to Australian areas in which these factors may have been operative.

MUSEUM AND TRANSIT ROOM

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

MUSEUM

by

D.H. McColl

COLLECTIONS

The gem-quality ruby discovered in the Harts Range of Central Australia was the principal topic of mineral research this year, and was also foremost among new specimen acquisitions. Ruby had long been considered a scarce to unobtainable gemstone in Australia, despite our prominence in sapphire production, and its discovery in a commercially significant deposit is of great interest. Hillrise Properties Ltd, the principals in this discovery, have donated a considerable quantity of ruby for research purposes as well as a superb display specimen.

Various acquisitions continue to enhance the scope and quality of our collections; they are currently obtained mainly by exchange and, to a lesser degree, purchase. Donations have been scarce and very minor, indicating the investment value which is now commonly ascribed to fine mineral, and also to a lesser extent fossil, specimens. Notable among the Museum's new material is a suite of metallic minerals from classical British mining sites, sent by the British Museum; a meteorite of the hexahedrite variety and a tektite from South Georgia received from Mr W. Zeitschel of West Germany; various Spanish minerals which came from Mr M. Borras of Zaragoza; and from Australia some unusual ferrocalcites from a Victorian basalt quarry, some striking smoky quartz from the Grampians area of Victoria and a slab of precious opal from Coober Pedy, S.A. Our emphasis has always been directed toward Australian material, but these have been increasingly hard to get except by personal collection or by representation through mining companies.

The first exhaustive stocktake of the accountable museum collections was carried out during early 1979. About fifteen thousand specimens were checked and about twenty discrepancies discovered -- eight of these specimens have subsequently been found by museum staff, and a few more are expected to be located in due course, especially during the recataloguing of the Doo Collection. A minor theft of two and possibly three specimens was confirmed, emphasising the need for continuing security measures. The entire museum collections would currently have a negotiable value in the vicinity of $500 000.

RESEARCH

Most work this year concentrated upon the ruby occurrence in Central Australia. The companies involved gave BMR exclusive rights to make the investigation of the geology and gemmology, and accordingly an initial descriptive paper was published in the September Australian Mineralogist. The authors were D.H. McColl & R.G. Warren. The same paper has been offered to the Mineralogical Record for international publication.

A deposit of kornerupine and sapphirine in a nearby part of the Central Australian Arunta Inlier was also investigated by the same authors and a report on it has also been offered to 'Mineralogical Record'.

MUSEUM SERVICES

Mineralogical, gemmological, and petrological enquiries of an extremely varied nature and over a wide range of levels continue to be made at the museum. Sundry services are still performed for BMR officers, other government departments, and local institutions which this year included the Australian National University, the Canberra College of Technical and Further Education, the A.C.T. Lapidary Club, the Canberra Gem Society, the Bathurst Gold Mining Museum, Queanbeyan District Scouts, the Australian-American Association, the RAAF Wives Association, the Civic VIEW Club, the Womens International Club, and the Wesley Centre.

Investigations made for other government departments included the Brisbane office of the Official Receiver in Bankruptcy concerning disputed ownership of a large golden sapphire. Minor services of an advisory nature were also provided for the Department of Industry and Commerce, the Department of Overseas Trade, and the Department of Home Affairs.

EDUCATION

Requests for assistance to A.C.T. schools teaching the geosciences have diminished somewhat during the current year. Requests for group visits by classes only came from Telopea Park High School, Holder High School, and a few very small groups accompanied by a single teacher. There were also a few requests for advice and assistance with excursions around the Canberra environs, but these two have been decreasing despite a promotional talk given to the Science Teachers Association by J. Price in August.

Demand for the sets of rocks and minerals which we provide as teaching aids, however, has continued at a moderate level and requests came from as far away as Darwin. Nine sets, each now consisting of about 150 specimens, were supplied this year. Our bulk stocks have also been augmented by field collecting to meet the demand for some time to come.

EXHIBITIONS

Last November a display entitled 'Minerals of Australia' was prepared for the annual exhibition of the Canberra Gem Society. It featured the 1976 Geological Map of Australia as a centrepiece and was surrounded by large specimens and photographs. Gold was featured as a major part of this exhibition, which was attended by 3000 people after an official opening by Senator J. Knight. The same exhibit was repeated in South Australia during the National Gemboree in March, which was seen by a further 7000 people and opened by the Governor of South Australia.

For the first exhibition held by the A.C.T. Lapidary Club, in the Albert Hall in August, we provided a display consisting of two showcases illustrating the systematic classification of minerals and one showcase with the principal types of fossils (prepared by Miss J. Gilbert-Tomlinson). It was attended by 5000 people and was the most successful function of its type ever conducted in Canberra. The showcases with BMR displays have been returned to the corridors of the Anzac East Building.

In August the 5th National Exhibition of Minerals was held at Waverley in Melbourne, and we assisted Hillrise Properties Ltd to prepare a display of the geology and gemmology of the Harts Range ruby deposit. Seminars about the ruby were presented at this function and were a great source of interest. The same display was exhibited at the Adelaide Gem and Mineral Show, Wayville, South Australia, in October.

VISITORS

Seven hundred and twenty-two people are recorded as having visited the museum this year, which includes the few school groups but excludes BMR personnel. This is a similar number to last year, down somewhat on school children, but an increase in the general public. The displays are still restricted to eleven original BMR showcases, plus several cases which came from the Sydney regional office and are now in the reception area of the Assistant Director (Geology).

Most visitors come with fairly casual or recreational enquiries like those evoked by the current interest in gold prospecting with metal detectors. Others bring quite complex rock, mineral, or gem materials for identification which may require more sophisticated techniques. Children wanting information and chips of specimens for school projects are also frequent callers. Most enquiries, however, are by mail or telephone.

TRANSIT ROOM

by

M.S. Amar

Survey Party samples requiring petrological, petrographic, analytical, radio-isotope, or other investigations are forwarded to contractors or the relevant BMR laboratories through the Transit Officer.

The total number of samples processed from 1 October 1978 to 30 September 1979 are as follows:

Thin-section preparations		3368
Polished thin sections		567
Impregnated thin sections		21
Unconsolidated thin sections		8
Universal stage sections		2
Isotopic age determinations (various)		224
Chemical analyses (various)		3448
X-ray diffraction determinations		3
	Total	7430

CONFERENCES AND COURSES

Apart from the mineral exhibitions referred to earlier, Section officers attended only one conference and no courses.

G. Jacobson attended the Groundwater Pollution Conference of the Australian Water Resources Council in Perth on 19-23 February, at which he presented a paper by himself and D.E. Smith (ANU) titled 'The application of fluorometric dye techniques to groundwater pollution problems with special reference to studies in Canberra'.

PUBLICATIONS AND RECORDS

PUBLICATIONS AND RECORDS

In this section of the report publications, Open File Records, and Professional Opinions (the latter two categories are regarded as unpublished) prepared in the Geological Branch are listed. The lists include those prepared in the Branch during the year and those prepared in earlier years and issued during the period under review. The period covered is November 1978 to October 1979. The categories of listing are given below, together with the number of papers or maps in each category (corresponding figures for 1978 are shown in brackets).

Bulletins	: Published 6 (15) or in press 9 (7) : With editors 8 (17)
Reports	: Published 6 (3) or in press 1 (3) : With editors 3 (1)
Mineral Resources Reports	: Published 1 (1)
Contributions to BMR Yearbook	: Published 8
Contributions to AMI Review	: In press 1
BMR Journal of Australian Geology and Geophysics	: Published 23 (33) or in press 2 (6) : With editor 6 (8)
Outside Publications	: Published 79 (53) or in press 83 (51) : Submitted and accepted 31 (20), or in preparation 9 (13) (for BMR authors 'in preparation' means that the paper is with editors).

Maps. Maps are geological maps unless otherwise stated.

1:250 000 scale Maps

Colour edition, with explanatory notes (both map and notes are at least at the stage indicated)

	: Published 13 (24) or in press 3 (13) : With editors 5 (6)
Preliminary edition (no notes)	: Published 10 (7) : Being drawn 2 (11)

1:100 000 scale Maps

Colour edition	: Published 0 (2) or in press 5 (2) : With editors 4 (6)
Geochemical maps	: Published 11 (5)
Preliminary edition	: Published 15 (8) or in press 2 (1) : Being drawn 10 (18)

Special Maps	:	Published 2 (0) or in press 6 (0)
	:	With editors 7 (6)
	:	Preliminary edition published 2 (4)
Records	:	Issued 34 (48)
	:	With editors 22 (13)
	:	In preparation (being edited within the Geological Branch) 17 (15)
Professional Opinions	:	Issued 40 (16)
Other unpublished works	:	3

Numbers against authors' name indicate that the author

1 was formerly a BMR officer

2 is, or was, an officer of an Australian State Geological Survey

3 is, or was, a member of the staff of the Baas Becking Geobiological Research Laboratory, and is not, or was not, a BMR officer

4 is, or was, a member of a university or other tertiary educational institution

5 is not, or was not, a BMR officer and does not fall into categories 1 to 4.

6 Dr D.F. Sangster, Geological Survey of Canada, worked in Geological Branch from May 1977 to May 1978 under an exchange arrangement.

Year of publication or issue is not shown unless it is known to be other than 1979.

BULLETINS

PUBLISHED OR IN PRESS*

167	SENIOR, B.R. MOND, A. HARRISON, P.L.	Geology of the Eromanga Basin.
172	[1]OPIK, A.A.	Middle Cambrian Agnostacea.
*182	[1]COOK, P.J. MAYO, W.	Geochemistry of a tropical estuary (Broad Sound, Queensland).
184	[4]RICH, P.V.	The Dromornithidae
185	[4]TASCH, P. JONES, P.J.	Carboniferous, Permian, and Triassic Conchostracans of Australia - Three new studies.
*186	SHERGOLD, J.H.	Late Cambrian trilobites from the Chatsworth Limestone, western Queensland.
*189	BURGER, D.	Palynological studies in the Lower Cretaceous of the Surat Basin, Australia.
*190	NICOLL, ROBERT S. [1]DRUCE, E.C.	Conodonts from the Fairfield Group, Canning Basin, Western Australia.
195	DAVIES, P.J.	Marine geology of the Continental Shelf of southeast Australia.
*197	BLAKE, D.H. HODGSON, I.M. [2]MUHLING, P.C.	Geology of The Granites-Tanami region, Northern Territory and Western Australia.
*199	EXON, N.F. WILLCOX, J.B.	The Exmouth Plateau: stratigraphy, structure and petroleum potential.

200	[1]DRUCE, E.C. RADKE, B.M.	Geology of the Fairfield Group, Canning Basin, Western Australia.
*202	[1]SMART, J. [2]GRIMES, K.G. DOUTCH, H.F. PINCHIN, J.	Geology of the Carpentaria and Karumba Basins.
*203	VANDEN BROEK, P.H.	The urban and engineering geology of the proposed Darwin East urban development area, N.T.
*204	OWEN, M. WYBORN, D.	The Geology and Geochemistry of the Tantangara and Brindabella 1:100 000 Sheet areas, A.C.T. & N.S.W.

WITH EDITORS

187	SHERGOLD, J.H.	Idamean (late Cambrian) trilobites, Burke River Structural Belt, western Queensland.
198	WELLS, A.T.	Evaporites in Australia.
205	KENNEWELL, P.J. [1]HULEATT, M.B.	Geology of the Wiso Basin, Northern Territory.
-	JACKSON, M.J. [2]VAN DE GRAAFF, W.J.E.	Geology of the Western Australian part of the Officer Basin.
-	[1]KENNARD, J.M.	The Arrinthrunga Formation: Upper Cambrian epeiric carbonates in the Georgina Basin, central Australia.
-	MARSHALL, J.F.	Sediment distribution, composition, and geochemistry: southern Queensland and northern New South Wales continental shelf.
-	STAGG, H.M.J. EXON, N.F.	The geology of the Scott Plateau off northwestern Australia.

\- Palaeontological papers.

DICKINS, J.M.	A Permian invertebrate fauna from the Warwick area, Queensland, and the effect of water temperature on correlation.
SKWARKO, S.K.	Mesozoic molluscs from Papua New Guinea and northern Australia (6 papers, as below).
	Some Neocomian bivalves from northern Queensland, northeastern Australia.
	A new late Mesozoic trigoniid and other bivalves from near Olsobip, Western Papua New Guinea.
	First report of Megatrigoniinae/bivalvia Cretaceous from Papua New Guinea.
	Nototrigonia cinctuta (bivalvia: mainly Early Cretaceous) in northern Queensland and Papua New Guinea.
	On the Trigoniinae, Nototrigoniinae and Austrotrigoniinae.
	Australian Cretaceous ammonites in the island of New Guinea.
- YOUNG, G.C. [1]GORTER, J.D.	A new fish fauna of Middle Devonian age from the Taemas/Wee Jasper region of New South Wales.
- BELFORD, D.J.	Co-occurrence of middle Miocene larger and planktic smaller Foraminifera, New Ireland, Papua New Guinea.

REPORTS

PUBLISHED OR IN PRESS*

193	SKWARKO, S.K.	Stratigraphic tables, Papua New Guinea.
200	BLACK, L.P.	Isotopic ages of rocks from the Georgetown/Mount Garnet/ Herberton area, north Queensland.
209	JOHNSON, R.W. [4]CHAPPELL, B.W.	Chemical analyses of rocks from the late Cainozoic volcanoes of north-central New Britain and the Witu Islands, Papua New Guinea.
211	[1]DRUCE, E.C. SHERGOLD, J.H.	Annotated bibliography of the Georgina Basin, Northern Territory and Queensland.
212		Geological Branch Summary of Activities, 1978.
*214	WALTER, M.R.	Adelaidean and Early Cambrian Stratigraphy of the South-western Georgina Basin: correlation chart and accompanying notes.
217	DERRICK, G.M.	Geology and mineral potential of red-bed and associated environments in the Mount Oxide region, northwest Queensland.

WITH EDITORS

216	STEWART, A.J. et al.	Stratigraphic definitions in the Arunta Block.
-	RADKE, B.M.	Lithostratigraphy of the Ninmaroo Formation (Upper Cambrian-Lower Ordovician), Georgina Basin.

-	WARREN, R.G.	Geology and tectonic setting of the eastern Arunta Block.

MINERAL RESOURCES REPORTS

PUBLISHED

9	KNIGHT, N.D.	Molybdenum deposits.

CONTRIBUTIONS TO BMR 78

DOW, D.B.	Irian Jaya mapping project.
FERGUSON, JOHN	Kimberlites in southeastern Australia.
WELLS, A.T., MOSS, F.J.	Ngalia Basin Study.
GLIKSON, A.Y.	Pilbara geochemical project: studying some of the Earth's oldest rocks.
PERRY, W.J. SIMPSON, C.J.	Remote sensing: a bird's-eye view for geologists.
KNUTSON, J.	Baas Becking Laboratory: Spencer Gulf/Adelaide Geosyncline/Stuart Shelf Project.
PAGE, R.W. BLACK, L.P.	Geochronology: calibrating geological time.
JACOBSON, G.	The rise and fall of Lake George.

CONTRIBUTION TO BMR 79 (in preparation)

JOHNSON, R.W.	Involvement in Papua New Guinea volcanological studies (foreign aid).

CONTRIBUTION TO AUSTRALIAN MINERAL INDUSTRY 1978 REVIEW

GIBSON, D.L.	Oil Shale.

BMR JOURNAL OF AUSTRALIAN GEOLOGY AND GEOPHYSICS

PUBLISHED OR IN PRESS*

Vol. 3(4), 1978	BULTITUDE, R.J. JOHNSON, R.W. [4]CHAPPELL, B.W.	Andesites of Bagana volcano, Papua New Guinea: chemical stratigraphy and a reference andesite composition, 281-295.
	DRUCE, E.C.	Clavohamulus primitus - A key North American Ordovician Conodont found in the Georgina Basin, 351-555.
	[5]HINZ, K. [5]BEIERSDORF, H. EXON, N.F. [5]ROESER, H.A. STAGG, H.M.J. [5]VON STACKELBERT, U.	Geoscientific investigations from the Scott Plateau off northwest Australia to the Java Trench, using R.V. Valdivia, 319-340.
	JAQUES, A.L. [4]CHAPPELL, B.W. [4]TAYLOR, S.R.	Geochemistry of LIL-element enriched tholeiites from the Marum ophiolite complex, northern Papua New Guinea, 297-310.
	SHAFIK, S.	The near-surface sediments of the Scott Plateau and Java Trench: nannofossil assessment and implications, 341-345.
	WALKER, K.R.	Involvement of Government organisations in geochemical surveys in Australia, 311-317.
4(1)	[4]BUREK, P.J. WALTER, M.R. WELLS, A.T.	Magnetostratigraphic tests of lithological correlations between latest Proterozoic sequences in the Ngalia, Georgina and Amadeus Basins, 47-56.

	COLWELL, J.B.	Zircons in the granitic rocks of southeastern South Australia, 72-76.
	[5] GOLDING, L.Y. WALTER, M.R.	Evidence of evaporite minerals in the Archaean Black Flag Beds, Kalgoorlie, Western Australia. 67-71.
	[2] GRIMES, K.G.	The stratigraphic sequence of old land surfaces in northern Queensland, 33-46.
	JACOBSON, G. SCHUETT, A.W.	Water levels, balance and chemistry of Lake George, New South Wales, 25-32.
	[6] SANGSTER, D.F.	Evidence of an exhalative origin for deposits of the Cobar district, N.S.W., 15-24.
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*1:1 000 000	Geology of the Carpentaria and Karumba Basins (2 sheets).	[1]SMART, J. [2]GRIMES, K.G. DOUTCH, H.F.
1:500 000	Solid geology of the Pine Creek Geosyncline.	NEEDHAM, R.S.

WITH EDITORS

1:10 000 000 Earth Sc. Atlas	Map (in press). Cainozoic cover and weathering. Notes with editor.	D'ADDARIO, G.E. PALFREYMAN, W.D. BULTITUDE, J.M.
1:10 000 000 Earth Sc. Atlas	Map (in press). Surface drainage and continental margins. Notes with editor.	D'ADDARIO, G.E. PALFREYMAN, W.D. BULTITUDE, J.M JONES, H.A. (Notes only).
1:1 000 000	Geology of the Wiso Basin, N.T.	KENNEWELL, P.J.
1:500 000	Geology of the Ngalia Basin, Northern Territory (2 sheets).	WELLS, A.T. MOSS, F.J. CHAN, R.A.
1:50 000	Geological map of Canberra and Queanbeyan, Australian Capital Territory and adjoining areas of New South Wales.	HENDERSON, G.A.M.
1:10 000	Central Canberra 1:10 000 Canberra Engineering Geology Series.	HENDERSON, G.A.M.
1:10 000	Coppins Crossing 1:10 000 Canberra Engineering Geology Series.	HENDERSON, G.A.M.

PRELIMINARY EDITION

PUBLISHED OR IN PRESS*

1:1 000 000	Geology of the Wiso Basin, N.T.	KENNEWELL, P.J.
1:500 000	Geology of the Ngalia Basin, Northern Territory.	WELLS, A.T.

RECORDS

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1976/68	[1]MENDUM, J.R. [1]TONKIN, P.C.	Geology of the Tennant Creek area, N.T.
*		
1978/12	SEIDEL, G.E.	Hydraulic calibration of the GABHYD model for the Great Artesian Basin.
1978/23	[1]DRAPER, J.J.	Progress report on Georgina geochemistry: results for the 1975-76 field survey.
1978/33	PASSMORE, V.L.	Explanatory Notes to accompany stratigraphic columns - Carnarvon Basin, Australia.
1978/38	PASSMORE, V.L.	Laura Basin Explanatory Notes and stratigraphic correlations.
1978/48	GLIKSON, A.Y. DERRICK, G.M.	Geology and geochemistry of Proterozoic basic volcanic belts, Mount Isa-Cloncurry, Northwest Queensland.
1978/54	JACKSON, M.J. MUIR, M.D. [4]LARGE, D.E. [1]BROWN, M.C. PLUMB, K.A. ARMSTRONG, K.J.	Field work report McArthur Basin Project, 1977.
1978/57	HENDERSON, G.A.M.	Geology of the Gundaroo-Westmead Park-Nanima area, N.S.W.
*1977/56	GARDINER, J.E.	Bibliography of Australian heavy-mineral sands.

1978/69	EVANS, W.R. BENNETT, D.G.	Geological and geophysical investigation of the proposed Mugga South landfill site, A.C.T., 1977.
1978/82	[1]BRISCOE, G. KELLETT, J.R. JACOBSON, G.	Canberra-Queanbeyan interaction study; geological factors in development planning.
1978/86	JACOBSON, G. HOHNEN, P.D. EVANS, W.R.	Groundwater pollution by hydrocarbons near the Center Cinema, Canberra City.
1978/88	COLWELL, J.B. BURNE, R.V.	Drilling in the Spencer Gulf area of South Australia, February and March, 1978.
1978/89		Geological Branch Summary of Activities, 1978.
1978/90	PURCELL, D.C. [5]TRAND, G. WILSON, E.G.	Melbourne cable tunnels geological investigation, 1978. Supplementary report.
1978/99	VANDEN BROEK, P.H. RAMSAY, D. SPARKSMAN, G.	Geological investigations for the Sullivan's Creek sewer tunnel, Canberra City, A.C.T., 1978.
1978/103	NEEDHAM, R.S. STUART-SMITH, P.G. CRICK, I.H. [2]ROARTY, M.J.	Mundogie 1:100 000 Sheet area data record.
1978/112	BULTITUDE, R.J. BLAKE, D.H. [2]DONCHAK, P.J.T.	Precambrian geology of the Duchess 1:100 000 Sheet area, northwestern Queensland - Preliminary data.
1979/8	FERGUSON, JOHN WYBORN, D. WYBORN, L.	CUMSEA 1979 - Excursion Guide.

1979/12	MACKENZIE, D.E. [2]WITHNALL, I.W. [2]BAKER, E.M.	Forest Home, North Head, and parts of Gilbert River and Esmeralda 1:100 000 Geological Sheets: Catalogue of Preliminary Field Data Compilation Sheets.
1979/15	PLUMB, K.A.	McArthur Basin Research, September Quarter, 1978.
1979/16	PLUMB, K.A.	McArthur Basin Research Project Progress Report, Decmber Quarter, 1978.
1979/17	SHERGOLD, J.H.	Georgina Research, December Quarter, 1978.
1979/19	PIETERS, P.E. RYBURN, R.J. TRAIL, D.S.	Geological reconnaissance in Irian Jaya, 1976 and 1977.
1979/21	DAVIES, P.J. [4]STEWART, D. THOM, G. McINTOSH, E. KORES, A.	A rock and sediment drill for use on coral reefs.
1979/26	EXON, N.F.	Preliminary deep sea sampling results, R.V. Sonne geological cruises off Western Australia in 1979.
1979/39	SHERGOLD, J.H.	Georgina Research, March Quarter, 1979.
1979/40	WALTER, M.R. [3]BAULD, J. BURNE, R.V. FERGUSON, J. JACKSON, M.J. [1]KENNARD, J. MUIR, M.D. [3]SKYRING, G.W.	Holocene carbonate environments in South Australia and Western Australia.

1979/42	TINGEY, R.J.	Workshop on Antarctic Geology, May 1979, Abstracts.
1979/44	PLUMB, K.A.	McArthur Basin Research, March Quarter, 1979.
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WITH EDITORS

1975/100	SHAW, R.D. WARREN, R.G. SENIOR, B.R. YEATES, A.N.	Geology of the Alcoota 1:250 000 Sheet area.
1978/100	MARSHALL, J.F.	Morphology and shallow structure of the continental shelf of southern Queensland and northern New South Wales.
1978/105	COLWELL, J.	The late Cainozoic sediments of southeastern South Australia - Lithology and Mineralogy.

1978/113	NEEDHAM, R.S. STUART-SMITH, P.G.	Progress report of the Alligator River Party, 1973-6 fieldwork.
1979/18	HENDERSON, G.A.M.	Geological data from drilling and excavations along the Molonglo Parkway between Black Mountain Peninsula and Acton, Canberra, A.C.T. 1977-78.
1979/24	[2]WILSON, I.H. [1]HILL, R.M. [2]NOON, T.A. [1]DUFF, B.A. DERRICK G.M.	Geology of the Kennedy Gap 1:100 000 Sheet area (6757), Queensland.
1979/27	PURCELL, D.C.	Molonglo Valley Interceptor Sewer, A.C.T., Engineering geology completion report, 1978.
1979/32	[1]GORTER, J.D. RASIDI, J.S. TUCKER, D.H. BURNE, R.V. PASSMORE, V.L. [1]WALES, D.W. FORMAN, D.J.	Petroleum geology of the Canning Basin.
1979/36	SHERGOLD, J.H. WALTER, M.R.	Stratigraphic drilling in the Georgina Basin, 1977-78.
1979/37	[1]ROSSITER, A.G. SCOTT, P.A.	Stream-sediment geochemical data - Seigal 1:100 000 Sheet area.
1979/38	[1]ROSSITER, A.G. SCOTT, P.A.	Stream-sediment geochemical data - Hedleys Creek 1:100 000 Sheet area.
1979/45	SWEET, I.P. [2]HUTTON, L.J.	Riversleigh and Gregory Downs 1:100 000 Sheets: catalogue of compilation sheets.

1979/47	SHAW, R.D. [1]LANGWORTHY, A.P. OFFE, L.A. STEWART, A.J. WARREN, R.G.	Geological report on 1:100 000 scale mapping of the southeastern Arunta Block, Alice Springs 1:250 000 Sheet area, Northern Territory.
1979/51	BROWN, C.M.	Arafura and Money Shoal Basins explanatory notes and stratigraphic correlations.
1979/52	BROWN, C.M.	Bonaparte Gulf Basin, explanatory notes and stratigraphic correlations.
1979/56	[2]WILSON, I.H. [2]NOON, T.A. [1]HILL, R.M. [1]DUFF, B.A.	Geology of the Quamby 1:100 000 Sheet area (6957), Queensland.
1979/57	PLUMB, K.A.	McArthur Basin Research, June Quarter, 1979.
1979/61		Geological Branch Summary of Activities, 1979.
1979/62	EXON, N.F.	Deep-sea sediments and manganese nodules from the southern Tasman Sea.
1979/64	VANDEN BROEK, P.H.	Soil and gravel deposits and extraction operations in the Canberra Region, A.C.T. and N.S.W. 1977.
1979/67	SCOTT, P.A. [1]ROSSITER, A.G.	Stream-sediment geochemical data - Georgetown 1:100 000 Sheet area, north Queensland.
1979/68	SCOTT, P.A. [1]ROSSITER, A.G.	Stream-sediment geochemical data - Gilberton 1:100 000 Sheet area, north Queensland.

IN PREPARATION

DERRICK, G.M. [2]WILSON, I.H.	Geology of Alsace 1:100 000 Sheet area (6858), northwest Queensland.
EVANS, W.R. JACOBSON, G. BENNETT, D.G.	Geological and geophysical investigation of the Pialligo landfill site, A.C.T.
GLIKSON, A.Y. [2]HICKMAN, A.H.	Geochemistry of Archaean volcanic successions, eastern Pilbara Block, Western Australia.
[1]GOLDSMITH, R.C.M.	Geological report on the construction of Googong Dam, Queanbeyan River, N.S.W.
[1]GOLDSMITH, R.C.M. EVANS, R.	Notes to accompany the geological map of Googong Reservoir area, N.S.W.
HOHNEN, P.D.	Geology and groundwater hydrology of Freshford, West Murrumbidgee urban development area.
JACOBSON, G. HILL, P.J.	Groundwater resources of Niue Island.
JACOBSON, G. HOHNEN, P.D.	Groundwater pollution by hydrocarbons in Canberra City - movement of pollution plume and effectiveness of recovery system.
KELLETT, J.R.	Investigation of the drainage of the Lanyon pediment basins.
[1]ROSSITER, A.G. SCOTT, P.A.	Stream-sediment geochemistry of the Seigal and Hedleys Creek 1:100 000 Sheet areas, northern Australia.

SHERATON, J.W.	Inventory of Antarctic rock specimens in Australian institutions.
STEWART, A.J. OFFE, L.A. GLIKSON, A.Y. WARREN, R.G.	Geology of the northwestern part of the Arunta Block, Northern Territory.
TOWNER, R.R. GIBSON, D.L.	The geology of the onshore West Canning Basin, Western Australia.
WARREN, R.G.	Review of available data on the crystalline basement in the Huckitta 1:250 000 Sheet area.
WARREN, R.G.	Summary of the Mineral Deposits in the Alice Springs 1:250 000 Sheet area.
WILSON, E.G.	Observations on geology, soils and groundwater relevant to pavement failure in Canberra, 1979.
[2]WITHNALL, I.W. OVERSBY, B.S. BAIN, J.H.C. [2]BAKER, E.M.	Geology of the Gilberton 1:100 000 Sheet area (7659), North Queensland.

PROFESSIONAL OPINIONS

ISSUED

Geol. 78.024	EVANS, R.	Kowen Forestry Settlement Bore: interpretation of aquifer test.
Geol. 78.025	GIBSON, D.L. BROWN, C.M.	Oil Shale Deposits, in southeast Queensland.
Geol. 78.027	NEEDHAM, R.S.	Mineral development potential of the Goodparla and Gimbat pastoral leases, Northern Territory - a professional opinion sought by Department & Environment, Housing and Community Development.
Geol. 78.029	WILSON, E.G.	Assessment of the effect of the construction of Googong Pipeline on a well in an adjacent property, Wickerslack Lane, South Queanbeyan, N.S.W.
Geol. 78.030	JACOBSON, G.	Canberra City Groundwater Pollution: Effectiveness of recovery system.
Geol. 78.031	MUIR, M.D. JACKSON, M.J.	Report on a visit to the Batchelor & South Alligator River areas 27-28 Sept., 1978.
Geol. 78.032	MUIR, M.D.	Carbonaceous fragments from a weathering profile near Lanyon, A.C.T.
Geol. 78.033	WALTER, M.R.	Report on a stromatolite from the Hammersley Basin.
Geol. 78.034	HOHNEN, P.D.	Preliminary assessment of seepage problem at Blocks 4, 5 and 6, Duffy Street, Ainslie, A.C.T.
Geol. 79.001	JACOBSON, G.	Geological aspects of water supply investigations, South Sumatra, Indonesia.

Geol. 79.002	CHAPRONIERE, G.C.H.	Samples from northwest of Kundiawa and from the Kundiawa-Gembogl Road.
Geol. 79.003	MUIR, M.D.	Cambrian age for an assemblage of microfossils from BMR Hay River No. 11B.
Geol. 79.004	NICOLL, ROBERT S.	Conodont color alteration in the Canning Basin subsurface.
Geol. 79.005	BURGER, D.	Preliminary palynological examination of OB-bores near Kota Bumi, south Sumatra.
Geol. 79.006	WILSON, E.G.	Statement on the geology, Block 24, Section 48, Deakin, A.C.T.
Geol. 79.007	HOHNEN, P.D.	Groundwater conditions, Hospital Services Complex, Mitchell, A.C.T.
Geol. 79.008	HOHNEN, P.D.	Comments on geological and hydrogeological aspects of Mr J. Barries' report dated June, 1978.
Geol. 79.010	MUIR, M.D.	Palynological examination of microfossils from the Observatory Hill Beds, Wilkinson No. 1 DDH, Officer Basin, S.A.
Geol. 79.011	EXON, N.F.	The prospectivity of the Christmas Island region for petroleum and other minerals.
Geol. 79.012	WILSON, E.G.	Brief review of geology of La Tour Koenig Housing Estate, Mauritius and its relevance to development.
Geol. 79.013	RADKE, B.M.	Saddle dolomite in Carpentaria Exploration Company Drillhole WBS1037, Sorby Hills, Bonaparte Gulf Basin.

Geol. 79.014	CHAPRONIERE, G.C.H.	Samples from the Kepala Burung area, Irian Jaya, 1978.
Geol. 79.015	JACOBSON, G.	Canberra City groundwater pollution effectiveness of pumping bore.
Geol. 79.016	JACOBSON, G.	Groundwater resources of Niue Island.
Geol. 79.017	NICOLL, ROBERT S.	Preliminary Report on conodonts from the Hole NBF1002, Bonaparte Gulf Basin.
Geol. 79.018	NICOLL, ROBERT S.	Conodont color alteration in Petroleum Exploration Well Ethabuka 1, Queensland.
Geol. 79.019	JACOBSON, G.	Condor Creek bridge approach, A.C.T.
Geol. 79.020	CHAPRONIERE, G.C.H.	Micropalaeontological report on samples from the Markham and Wau 1:250 000 Sheet areas, Papua New Guinea.
Geol. 79.021	JACOBSON, G.	Groundwater investigations at Hume Industrial Estate, A.C.T.
Geol. 79.022	CHAPRONIERE, G.C.H.	Micropalaeontological report on a sample from the Louisville Seamount, Central South Pacific Ocean.
Geol. 79.023	SHAFIK, SAMIR	Calcareous nannofossil estimation of a sample from the flanks of the Louisville Seamount.
Geol. 79.024	JONES, P.J.	Examination of four samples from AMAX Ellendale No. 1 Well. (SE 51/8 Lennard River 1:250 000 Sheet, W.A.).

Geol. 79.025	TRUSWELL, E.M.	Palynological age determination of a sample from the Karawari River, Papua New Guinea.
Geol. 79.026	WILSON, E.G.	Major Airport Needs of Sydney (MANS) Study - Geological Considerations.
Geol. 79.027	JACOBSON, G.	Groundwater pollution by petrol at NRMA building, Canberra, A.C.T.
Geol. 79.028	YOUNG, G.C. NICOLL, R.S.	Report on samples from Irian Jaya submitted for micropalaeontological examination.
Geol. 79.029	SHAFIK, SAMIR	Nannofossil biostratigraphy of Lynedoch No. 1 Well, Northern Territory.
Geol. 79.030	JONES, P.J.	Examination of samples from two Utah Development Corp. Wells in the Laura Basin. (SD55/9 Cape Melville 1:250 000 Sheet, Qld.).
Geophys. 79.004	EXON, N.R. STAGG, H.M.J.	The prospectivity of the Scott Plateau off northwest Australia for petroleum and other minerals.
MR 79.004	ERSKINE, J.C. HALDANE, A.H. WILSON, E.G.	Comment on the Jabiluka Uranium Project Final Environmental Impact Statement.

OTHER UNPUBLISHED WORKS

BAIN, J.H.C	A study of the Jubilee Plunger gold-silver - base metals deposit, Etheridge Goldfield, N. Queensland.	M.Sc. thesis James Cook Univ., North Queensland.
DERRICK, G.M.	Proterozoic igneous and sedimentary rocks and associated metamorphism and metasomatism at Mary Kathleen, northwest Queensland.	Ph.D. thesis, University of Queensland.
LORENZ, R. GIBSON, D.L.	Occurrence of oil shale deposits in Australia.	BMR Library Bibliography 9.