BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT 239

BMR MICROFORM MF182

GEOLOGICAL BRANCH ANNUAL SUMMARY OF ACTIVITIES 1981

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

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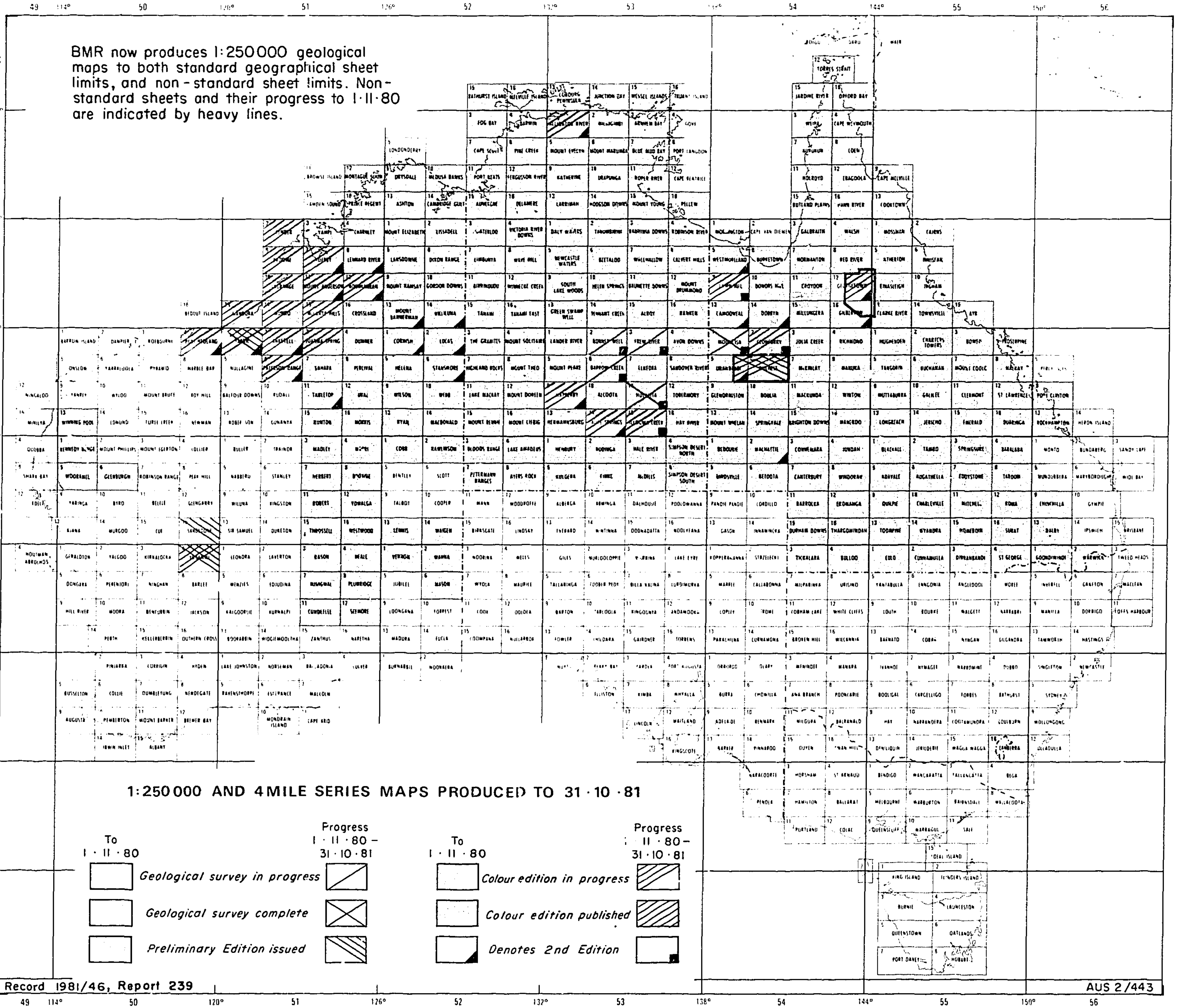


AUS 2/443 (Overlay)

ANTARCTICA

1:250000 SERIES MAPS

PRELIMINARY EDITION ISSUED – TO 31·10·77

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

No maps were issued in period 1·11·77 to 31·10·81

ENDERBY LAND FIELD STUDIES

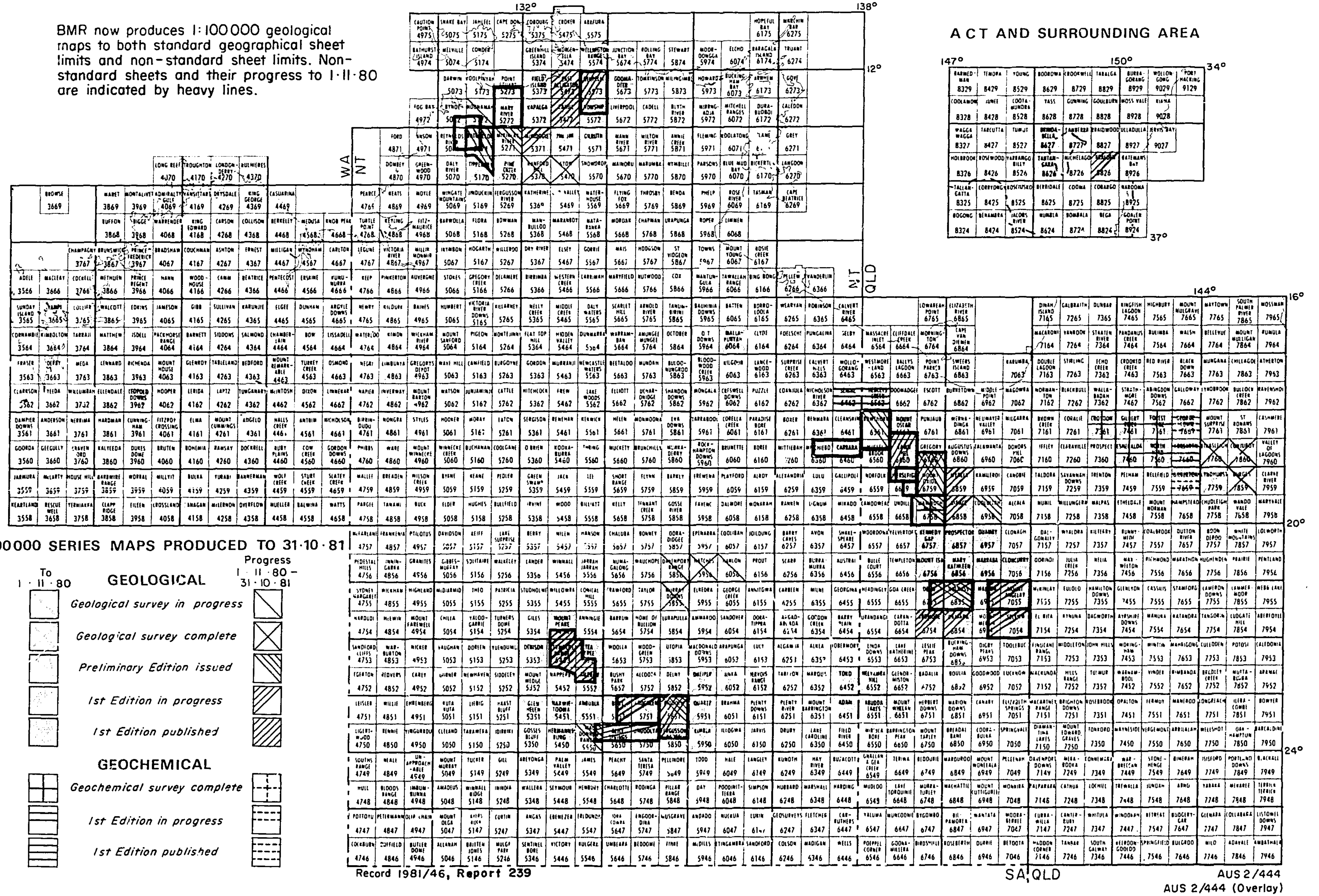
SEE UNDERSHEET

Geological mapping – Summer 76/77

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

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

FRONTISPIECE (1)


BMR now produces 1:100 000 geological maps to both standard geographical sheet limits and non-standard sheet limits. Non-standard sheets and their progress to 1·11·80 are indicated by heavy lines.
ACT AND SURROUNDING AREA
132°
138°
147°
150°
34°
37°
12°
144°
16°
20°
24°
WA
NT
NT
QLD
SA
QLD
1:100 000 SERIES MAPS PRODUCED TO 31·10·81
To 1·11·80
Progress 1·11·80 – 31·10·81
GEOLOGICAL
Geological survey in progress
Geological survey complete
Preliminary Edition issued
1st Edition in progress
1st Edition published
GEOCHEMICAL
Geochemical survey complete
1st Edition in progress
1st Edition published
AUS 2/444
AUS 2/444 (Overlay)

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GENERAL SUMMARY

This Report generally covers the period November 1980 to October 1981

SEDIMENTARY SECTION

by

G.E. Wilford

The preparation and publication of syntheses of information on sedimentary basins continued: major bulletins on the geology of the Wiso (No. 205) and Officer Basins (No. 206) were published, and texts with their accompanying geological and geophysical maps describing aspects of the geology of the Ngalia and Canning Basins are with editors. The last of the 1:250 000 geological maps and Explanatory Notes arising from the remapping of the Canning Basin were submitted to the editors, thus completing the Section's long contribution to the systematic reconnaissance mapping of the continent.

The main emphasis in Georgina Basin studies has again been the publication of results, although palaeontological and geochemical studies have continued. Much of the work has been oriented towards the diagenetic history of and the nature and abundance of organic matter in various units, in order to better assess the hydrocarbon potential of the basin.

The main geological activities within the multidisciplinary McArthur Basin Project, apart from field checking, have comprised a continuation of sedimentological and mineralisation studies. Revisions to the stratigraphy are being incorporated in a 1:100 000 scale map of the ABNER RANGE REGION*. Detailed studies of some clastic units are revealing a range of depositional environments ranging from fluviatile through evaporative to deep water. Stable-isotope studies of stratabound mineral deposits associated with some of the units, including the larger Pb-Zn-Cu ore bodies of the McArthur-Cloncurry region, indicates that they formed from high-temperature emanations such as those found in modern oceans, rather than from the process of in-situ low-temperature sulphate reduction.

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* See footnote page xvi

Revision mapping of the CANBERRA* 1:250 000 Sheet area at 1:100 000 scale is now well advanced. The ARALUEN 1:100 000 map and commentary are with the editors and work is well advanced on the CANBERRA 1:100 000 map and commentary; the remaining four maps and texts have been published, two by the Geological Survey of New South Wales. Detailed studies of the Silurian volcanic rocks of the western part of the area show that they can be geochemically matched with both S and I-type granitoid plutons, and have revealed information on their depth and temperature of formation. Isotopic age determinations on the Laidlaw Volcanics, interbedded with age-diagnostic fossiliferous units, indicate that the Silurian-Devonian boundary should be placed at no younger than 410 m.y.

The joint BMR/State study of the hydrogeology of the Murray Basin was mainly concerned with clarifying and documenting the complex stratigraphy of the basin. Eustatic control of facies distribution is evident and affects, for instance, the distribution of brown coal. As part of the project, studies were completed on the Devonian sub-basins beneath the northern Murray Basin and on the many Permian sub-basins. The Devonian sequence has low prospectiveness for gas but the easternmost Permian units contain steam coal of commercial interest.

Work on the Great Artesian Basin was oriented towards geochemical and isotope studies with a view to assisting in the study of hydrocarbon migration/trapping mechanisms.

The photogeology and remote sensing group acquired a digital image analysis system for research into geological applications of Landsat digital data.

Under the auspices of the West German-Australian Science and Technology Agreement, and using the German research vessel Sonne, an investigation of the superficial deposits on the continental shelves of northern New South Wales and southern Queensland was carried out with the aim of providing the stratigraphic framework for locating possible offshore accumulations of heavy minerals. Seismic reflection profiles, surface sampling, and coring revealed three sequences separated by unconformities overlying acoustic basement. In general a variety of early Holocene and late Pleistocene shallow marine, estuarine, lagoonal, and weathered subaerial sediments are overlain by marine late Holocene sands. Sand bodies up to 20 m thick have accumulated near prominent headlands and contain surface heavy-mineral enrichments in a few places.

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* See footnote page xvi

The joint BMR/CSIRO, partly NERDDP-funded project to study the Permian coals of eastern Australia has concentrated on improving stratigraphic correlations both within and between the Bowen and Sydney Basins using global eustatic changes where appropriate and field investigations where necessary. Some of the first structure and isopach maps have been prepared using computer techniques. The second joint BMR/CSIRO, partly NERDDP-funded project, designed to study the Toolebuc Formation as a possible future source of shale oil, was mainly concerned with the drilling and geophysical logging of fully cored holes through the unit where critical facies changes are present. Review papers on oil shale in Australia were prepared.

The description and curation of the national fossil collections were continued by the Palaeontological Group, and biostratigraphic studies were concentrated and expanded in those parts of the stratigraphic column of immediate interest to the exploration industry. Studies of fossil chitinozoans were initiated. Fossil groups from all Phanerozoic systems were studied, including material from New Guinea, Antarctica, and offshore areas. A highlight was the identification, in modern muds in offshore Antarctica, of recycled microfossils of Permian, Jurassic, Cretaceous, and Tertiary ages, implying the presence of sedimentary sequences of these ages beneath the ice cap.

METALLIFEROUS SECTION

by

K.R. Walker

In a year of changing work emphases and priorities in the Bureau, the Metalliferous Section has continued to maintain a strong presence in mineral province studies. Field research supported by laboratory investigations has continued in the Pine Creek Geosyncline and the southeastern Georgetown Inlier, and has now started in the Davenport Geosyncline. The final stages of the Mount Isa/Duchess, Central Georgetown/Croydon, and Yilgarn projects have involved intensive office and laboratory studies; the centre of activity for the Mount Isa project shifted in April/May to the Geological Survey of Queensland owing to staff movements then. In all the project areas BMR is collaborating closely with the State Surveys. Laboratory studies this year have proved particularly useful in achieving geological understanding of some study areas.

In keeping with previous years a steady flow of manuscripts issued from the Section throughout the year, and at year's end these amounted to 115 publications and 44 maps (most being Preliminary editions); in addition, 24 Records were completed. Progress in maps resulting from the mineral province studies are shown in Frontispieces 1 and 2.

The Arunta Project is now entirely concerned with reporting of results and map production from previous years' field research. The Mount Isa, Duchess, and Yilgarn Projects are at a similar stage. A symposium and field excursion on the Mount Isa Project were held in September at Mount Isa, and, for the Arunta Project, the International Conference on Deformation Processes in Tectonics and an excursion at Glen Helen, Alice Springs, in August coincided with the final stages of this project. Both meetings served as useful workshops to present the latest ideas on the geology of the areas, and to get the views of others at the crucial reporting stage. In addition, the Mount Isa Project in particular has benefited greatly from the completion of petrological, geochemical, and isotopic dating laboratory studies which have helped resolve some of the earlier differences in geological interpretation of the area. Studies have concentrated on U-Pb dating of critical stratigraphic units, and on the geochemistry of the felsic volcanics and granitoid rocks in particular.

One interesting suggestion to emerge from the Yilgarn Project is that the Cook Well greenstone belt unconformably overlies banded gneiss. Also, the presence of an orthoquartzite unit at the base of the Maynard Hill greenstone belt implies that a sialic terrain was being eroded during deposition of the early greenstones.

The Davenport Party in their initial year of fieldwork achieved significant revision of the stratigraphy in the central part of the Davenport Geosyncline, through mapping HATCHES*, MURRAY DOWNS, and parts of DAVENPORT RANGE, HANLON, OORADIDGEE, and EPENARRA. At this stage, efforts have concentrated on establishing the stratigraphic sequence, and on studying the structure and volcanism of the Hatches Creek Group. The Geophysical Branch completed detailed aeromagnetic survey coverage of HATCHES and regional coverage of <u>BONNEY WELL</u>*; some rock collections were made for studying the physical properties of rock units to assist the geophysical interpretations.

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* Throughout this Annual Summary of Activities, names of map Sheets in the 1:100 000 and 1:250 000-scale series are printed in upper case; e.g. Riddoch 1:100 000 Sheet area is shown as RIDDOCH, and Alice Springs 1:250 000 Sheet area as <u>ALICE SPRINGS</u>.

Progress in the Pine Creek Geosyncline Project resulted in a better understanding of the regional stratigraphy, and efforts have concentrated on completing the field coverage of the investigation.

BMR involvement with Antarctic geology is continuing, through the secondment of geologists to the Australian National Antarctic Research Expeditions (ANARE) to carry out field research in Australian Antarctica; the 1980/81 summer season was spent by Sheraton in the Davis/Prydz Bay area. This year the Antarctic Research Policy Advisory Committee (ARPAC) became fully operational, and Tingey, as co-ordinator for Marine and Terrestrial Earth Sciences, assisted with the vetting and formulating of Antarctic Research programs. Antarctic project work in BMR also continues to involve joint work in isotopic and metamorphic rock studies with University researchers, and also contributes to co-operative work in research expeditions such as GANOVEX and the international geological expedition to northern Victoria Land.

This year Sheraton has reported on intrusive dykes that are used to discriminate between the Napier Complex and the younger Rayner Complex. In a paper that he presented to the Royal Meteorological Society, Tingey reviewed the terrestrial record of the development and fluctuation of the Antarctic ice cap. Wyborn has published a preliminary account of granitoid studies he made in Northern Victoria Land while an Australian participant in the West German GANOVEX expedition. Black has collaborated with Dr James and Mr Harley in reporting the results of geochronological, tectonic, and metamorphic investigations of the Archaean Napier Complex in Enderby Land.

In order to release results of current investigations early, the Lyndhurst Party reports comprehensively on their field observations and conclusions reached this year.

Work in volcanology concentrated on geochemical and petrological studies of individual volcanoes in Papua New Guinea, cataloguing data on Papua New Guinean volcanoes, completing volcanological and petrological reviews for various national and international projects, and completing a volume of papers in honour of the late R.J.S. Cooke and E. Ravian. In addition, Johnson has pursued his proposal for a Western Pacific volcanological institute to provide a facility for volcanological training in the region.

In the Petrological Laboratory, a considerable amount of attention has been given to the Pilbara volcanic geochemistry, and a report on the first phase was completed and work on the second started. A study of the BMR-Hollmayer collection revealed an unusual polymict breccia, the Nilpena ureilite, and a new Australian carbonaceous chondrite, the Tibooburra meteorite. Among the alkaline ultramafic rocks studied were ultrapotassic rocks of the Kimberley region of Western Australia; in particular, the leucite lamproites and associated kimberlitic rocks are being studied with regard to their significance to diamond exploration.

In the Geochemical Laboratory much of the effort has been devoted to advancing work on previously conducted geochemical surveys, and to a geochemical study of the Lower Proterozoic metasediments in the Pine Creek Geosyncline, and a study of uranium genesis at Nabarlek.

Using U-Pb zircon dating in conjunction with the Rb-Sr method, the geochronologists have resolved some important time-rock relationships at Mount Isa, Tennant Creek, Cobar and Western Tasmania. Isotopic studies in these regions are nearing completion, but similar research will continue in the Georgetown and Antarctic regions. A study of Sm-Nd analyses was used for the first time to determine initiation ages of rocks in some of the areas. A Rb-Sr isotopic study of igneous activity, metasomatism, and uranium mineralisation in the Mary Kathleen syncline has resulted in the discovery of a younger than expected age for this mineralisation.

Staff this year have had greater participation in international conferences than previously, attending by invitation 5 major scientific gatherings. In addition, significant contributions have been made to national conferences, in particular to the Symposium on Mount Isa geology and the International Conference on Deformation Processes in Tectonics.

GEOLOGICAL SERVICES SECTION

by

E.K. Carter

During the twelve months under review 44 reports, papers, maps, and map commentaries emanating from the Section were issued, or were in process of issue (i.e., submitted to supervisor) at the end of the period. This number includes some listed last year which were then in course of issue. Seven (7) reports, papers, maps and map commentaries were published, 12 are in press or in process of publication; 19 Records and Professional Opinions were issued and 6 are in course of issue.

Hydrogeological research and applied investigations occupied the major part of the Engineering Geology and Hydrogeology Subsection's effort. Within or adjacent to the ACT the studies of the characteristics of and water quality in a variety of fractured-rock aquifers continued, and assembly of bore data was nearly completed. The testing of two experimental bore fields in volcanic and volcanogenic metasedimentary rocks in the southern Tuggeranong District gave some valuable information on the hydraulic behaviour and water chemistry of the aquifers intersected. An investigation involving the drilling and testing by 48-hour pump tests of several bores, to establish a source of groundwater for Tharwa village, gave further information in a highly fractured volcanic-granitic terrain in which an interconnection exists with the Murrumbidgee River. Further progress was made in the study and characterisation of the hydrogeology of the Upper Yass River and Orroral River Representative Basins. These four projects have added to the data base needed to produce a hydrogeological map of the ACT and environs, a continuing project of the Subsection.

Fieldwork and drilling in the Begargo Creek area, near Lake Cargelligo, NSW, was completed. This work is part of a joint study with the Division of Land Use Research, CSIRO, of the occurrence of ground salinity in the area, and has led to an understanding of the genesis of soil salinity.

A long-term study of groundwater seepage and the water balance of Lake Windermere, Jervis Bay Commonwealth Territory, was completed and reported on; it identified the relationship between the lake and nearby Quaternary sands, and established that extensive resources of groundwater are available for use. The monitoring of Lake George, NSW, continued.

Hydrogeological studies of two South Pacific islands contributed to Australia's foreign aid program: adequate supplies of unpolluted water were located at Tarawa Atoll, Kiribati, and a water supply in limestone terrain for a proposed school on Espiritu Santo, Vanuatu, was identified. Assistance was also given for the development of a water supply on Niue Island.

ACT urban geology studies included further work on the last two of six 1:10 000-scale Canberra engineering geology maps and commentaries, including drilling and field checking. The North Canberra map and notes are complete and those for South Canberra well advanced. The geological map of Canberra and Queanbeyan, scale 1:50 000, was printed; the accompanying commentary is in press. Investigations of a number of drainage and seepage problems, including pollution by petrol and wastes, were undertaken or continued. The geology of Parliament House site was recorded as excavation proceeded. Several other minor investigations were carried out, and two papers on aspects of the engineering geology of Canberra were prepared by, or in collaboration with, a visiting member of staff of Canberra College of Advanced Education.

Completion reports on geological aspects of the construction of Telecom cable tunnels, in Melbourne, were written.

Other environmental studies included a review of the Lake Way uranium deposit draft environmental impact statement, and a continuation of the joint AAEC-BMR study of overseas developments in the geological disposal of high level nuclear wastes.

In the Map Editing and Compilation Group, 25 maps were edited or given some form of editorial check (18 last year), and 6 (8) are in progress. Further work was done on the 1:5 000 000-scale 'Geology of Australia' map for the Atlas of Australian Resources, 3rd Series, for the Division of National Mapping, and the first draft of the accompanying commentary was substantially written. The notes to accompany the 1:2 500 000 geological map of Australia were completed, subject to colleague review.

Recording of stratigraphic names and definitions, and relevant bibliographic, geographic, and subject data to provide a flexible and useful retrieval capability, was maintained by the staff of the Central Registry of Stratigraphic Names. Input, which is recorded in a computer base, comes from current literature, Stratigraphic Nomenclature Subcommittees of the Geological Society of Australia, and prospective authors. Further additions of previously card-indexed data were prepared by contract for computer input. Three hundred and nine (309) new stratigraphic names and 118 definitions of units were indexed; 128 proposed names were reserved and 84 definition cards received: a total of 639 (894 last year). Six bimonthly variations lists and one deletions list were distributed; in addition, bimonthly current awareness lists by broad subject classification are now being produced for BMR staff.

A report on the occurrence of fluorite in Australia is almost ready for editing after incorporation of comments by State Geological Surveys.

The appointment, after a period of more than twelve months, of a new Museum Curator in January has enabled the Museum to function more fully. Collections were added to by field collecting, purchase, and exchange; and some of our collection holdings were accurately identified by instrumental determination. Displays were mounted at four interstate and ACT exhibitions, and the usual educational and visitor-information services were maintained. About 500 visitors were received. The Museum Curator started a research project on zeolites from the Gerringong Volcanics.

About 5400 samples for determinations of various kinds were handled by the Transit Room Officer (11 400 last year).

BAAS BECKING GEOBIOLOGICAL LABORATORY

by

M.R. Walter

Research within the Baas Becking Laboratory is directed at low-temperature processes in sedimentary basins. These range from the climatic, hydrological, chemical, and biological processes that control sedimentation and early diagenesis, through to the movement of fluids through lithified sediments. Such a program can encompass those processes that affect a hydrothermal solution when it cools and passes through sediments, or flows into a sedimentary basin, and those processes that occur when groundwater interacts with sediments. The aims of the program are to increase our understanding of the processes that produce low-temperature base-metal sulphide deposits, and now, as a new initiative within the laboratory, those processes that lead to hydrocarbon accumulations, particularly in the more ancient basins. Though the end results are obviously different, many of the processes ultimately leading to hydrocarbon accumulations and low-temperature metal sulphide mineralisation are the same. This applies not only to Pb-Zn deposits and oil in carbonate rocks (including Mississippi Valley type ores) but equally well to stratiform base-metal sulphide deposits. For instance, biological sulphate reduction not only produces sulphide ions that may precipitate metals, but also is one of the major processes that convert organic matter back to CO_2, thus affecting the distribution of organic matter in sediments and early diagenetic dissolution and cementation of carbonates. The development of permeability, and controls on the movement of fluids, are equally relevant research topics when studying the genesis of ore bodies or oil pools.

Until recently, little attention had been paid to the petroleum prospectiveness of Proterozoic basins. This is for historical rather than geological reasons:

1. for the first century of geology, until 20-30 years ago, the mistaken beliefs prevailed that virtually all Proterozoic rocks were metamorphosed well beyond the oil and gas generation windows and that no appropriate organic matter is present in rocks of this age;

2. many exploration concepts are derived from long experience in North America and elsewhere where the majority of Proterozoic basins are very deep or structurally complex.

Australia, however, is unusually well endowed with shallow, little metamorphosed Proterozoic basins more like those of Siberia which are known to contain one giant and many smaller gas fields, and one large oil field (available evidence supports the view that the hydrocarbons as well as their reservoir rocks are Proterozoic). For these reasons the Baas Becking program has been focussed on the Late Proterozoic to early Palaeozoic basins of Australia.

In addition to the early Palaeozoic and Proterozoic sequences, Australia is also unusually well endowed with Holocene analogues to ancient environments, which present unique opportunities for research. The studies in modern environments complement those on ancient sequences by providing important information on the primary and early diagenetic events which govern the early development of permeability, the formation and preservation of organic matter, the deposition and transformation of mineral species, particularly sulphides and carbonates, and the sedimentological setting of these processes.

SEDIMENTARY SECTION

Head: G.E. Wilford

PROVINCE STUDIES

BASIN SYNTHESES

STAFF: M.J. Jackson, A.T. Wells, F.J. Moss (Geophysical Branch), R. Towner, D. Gibson

Bulletins on the geology of the Wiso Basin (No. 205) and the Officer Basin (No. 206) were published. The text of a Bulletin on the geology of the Ngalia Basin is being edited. These Bulletins are accompanied by 1:500 000 or 1:1 000 000-scale coloured geological and geophysical maps. A preliminary edition 1:1 000 000-scale map of the Canning Basin was issued. The status of the 1:250 000-scale geological maps and notes covering these basins is shown in Frontispiece 1.

CANNING BASIN MAPPING

by

R.R. Towner & D.L. Gibson

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

Systematic field investigation of the 31 Sheet areas comprising the project was carried out yearly from 1972 to 1977. By the end of October 1981, 17 Explanatory Notes and maps were published and the remaining 14 were in press or in preparation (see Frontispiece 1).

GEORGINA BASIN PROJECT

compiled by

J.H. SHERGOLD, Project Coordinator

STAFF: The following personnel (listed alphabetically) contributed to the Georgina Basin Project in 1981: E.C. Druce (Dept Trade & Resources), S. Elgueta (ANU, RSES), R.A. Fortey (British Museum, Natural History), M.E. Freeman (NTGS), M. Glikson (ANU, Biogeography), A.Hutton(Wollongong University), K.S. Jackson, P.J. Jones, J.M. Kennard, J. Laurie (NTGS), B.M. Radke, M.W. Sandstrom (ANU, RSES), M. Schmitt (University of Wurzburg), J.H. Shergold, C.J. Simpson, P.N. Southgate (ANU, RSES), M.R. Walter, G. Young.

During 1980/81 continued emphasis was placed on publishing the results of investigations initiated prior to 1980 and on undertaking research on core materials obtained during the 1980 drilling season. Proposals for specific research activities in the Georgina Basin, made in 1979, cannot be satisfactorily undertaken at the present time owing to continuing personnel losses. Only palaeontological and geochemical research projects are actively continuing; sedimentological and geophysical projects have been largely concluded. In particular, work progresses on core samples obtained from earlier drilling programs, and on compilation of data for the completion of map production.

SEDIMENTOLOGY/LITHOSTRATIGRAPHY (J.M. Kennard, B.M. Radke, J.H. Shergold, P.N. Southgate, M.R. Walter)

Lithostratigraphic studies in the Georgina Basin are now largely completed. Outstanding studies are those relating to the sedimentology of black shale formations, and the recognition of regional facies changes, particularly across HUCKITTA, in the southwest of the basin.

Adelaidean and early Cambrian lithostratigraphic units proposed for ADAM have been correlated throughout the southern part of the Georgina Basin. Five distinctive tectosomes separated by hiati have been recognised and widely correlated. In the Georgina Basin, the basal tectosome is represented by the Yackah beds in the Huckitta area. It is succeeded by a tillitic tectosome (Mount Cornish Formation, Yardida Tillite) equivalent to the Sturtian glacial event of the Adelaide Geosyncline, and this in turn is overlain by a predominantly arkosic tectosome which culminates in dolostone (Oorabra Arkose, Black Stump Arkose, Wonnadinna Dolomite). A fourth tectosome comprises fine sandstone and shale with localised conglomerate (Elyuah Formation, Grant Bluff Formation, Elkera Formation). The fifth, of early Cambrian age, again comprises sandstone and dolostone (Mount Baldwin Formation, Adam Shale, Red Heart Dolomite, Arumbera Sandstone II and III and Todd River Dolomite; M.R. Walter).

In the eastern part of the basin a suite of unusual highly skeletal halite pseudomorphs has been described from the early Middle Cambrian Ardmore Chert Member of the Thorntonia Limestone at Ardmore. The pseudomorphs occur as both moulds and casts in banded light and dark coloured chert. They are orientated parallel to the bedding and have been interpreted as halite grown within a brine pool which evaporated to dryness (P.N. Southgate).

The Lower-Middle Cambrian stratigraphy of the Marqua/Hay River areas has been revised. A basal clastic sequence (Adam Shale), comprising interbedded purple, green, and red shale and sandstone, is conformably overlain by a dolostone unit (Red Heart Dolomite) which contains late Early Cambrian or early Mid-Cambrian archaeocyathids. This sequence is overlain by a predominantly black shale/black carbonate interval (Hay River Formation) which is split into lower and upper parts by a persistent skeletal grainstone layer. Stratigraphic breaks occur below and above this grainstone (see biostratigraphic section below). The upper Hay River Formation passes conformably into a predominantly pale carbonate sequence, now referred to the Marqua Formation. This stratigraphy has been compiled from sequences penetrated in BMR Hay River Nos. 11, 11A, and 11B and Tobermory No. 14, supplemented by analysis of surface exposures on the Marqua Monocline (J.H. Shergold).

Studies on epeiric carbonate sediments in the Arrinthrunga and Ninmaroo Formations described in previous annual reports are now published (J.M. Kennard, B.M. Radke).

PALAEONTOLOGY/BIOSTRATIGRAPHY (E.C. Druce, M. Schmitt, P.N. Southgate, M.R. Walter, P. Jones, R.A. Fortey, J.H. Shergold).

Numerous microfossils have been detected in thin sections of Middle Cambrian chert samples from the Yelvertoft area of western Queensland. They were submitted for palaeontological determination by BHP, and as yet they have not been identified; they resemble diatoms (M.R. Walter).

Twenty samples from the Middle Cambrian Thorntonia Limestone and Currant Bush Limestone at localities in UNDILLA and RIVERSLEIGH have yielded prolific phosphatised skeletal residues after acid treatment. Phosphatised stromatolites referred to Ilicta cf. composita Sidorov have been recognised in the Riversleigh area 35 m above the base of the Thorntonia Limestone. Undetermined stromatolites also occur at a prominent disconformity surface on top of the Thorntonia Limestone between Thorntonia Station and D-Tree Bore. A variety of inarticulate brachiopods, molluscs, hyoliths, sponges, and rare trilobites have been found phosphatised in the Thorntonia Limestone. The basal Currant Bush Limestone is also phosphatic and has yielded a prolific fauna which includes agnostid trilobites of the Euagnostus opimus Zones.This fauna confirms a time break between the Thorntonia Limestone and Currant Bush Limestone in the area between Thorntonia and D-Tree, since faunas representative of the Triplagnostus gibbus and Ptychagnostus atavus Zones have not been recovered (P.N. Southgate, J.H. Shergold).

Palaeontological examination of BMR Tobermory 14, drilled in 1980, has been completed, and complements the faunal stratigraphy investigated earlier in the Hay River coreholes. In this hole the Red Heart Dolomite has yielded a poorly preserved phosphatic fauna - including inarticulate brachiopods, hyolithids, molluscs, sponges, and a single trilobite fragment - not unlike that of the Thorntonia Limestone. Succeeding black sediments of the lower Hay River Formation, however, contain species of Redlichia, Pagetia, Peronopsis and Xystridura, confirming an Ordian age for this part of the sequence. The supposed Templetonian is represented by a thin brachiopod coquina, as in Hay River 11. The upper Hay River Formation, black shales and thin dark carbonates, has yielded agnostid trilobites representative of the Ptychagnostus punctuosus Zone, and the overlying Marqua Formation, predominantly pale carbonate, trilobites indicating the latest Middle Cambrian zone of Leiopyge laevigata (J.H. Shergold).

Some 24 genera and 41 species or subspecies of Idamean and immediate post-Idamean trilobites have been described from the Pomegranate Limestone and lowest part of the Chatsworth Limestone in the central portion of the Burke River Structural Belt. Revisions have been made to earlier published taxa by Whitehouse, Öpik, and Henderson. The zonation proposed by Henderson for Georgina Limestone sequences at Glenormiston can also be applied in the Burke River area, but it is difficult to differentiate the Erixanium sentum Zone from earlier and younger assemblages. The incoming of the Irvingella tropica Zone is regarded as introducing an as yet unnamed biochronological stage which succeeds the Idamean (J.H. Shergold).

Taxonomic descriptions of some 13 generic taxa of early Ordovician (Arenigian) trilobites from the Toko Syncline and neighbouring areas is continuing (R.A. Fortey, J.H. Shergold). Descriptions of early Ordovician conodonts, also from the Toko Group, is proceeding (E.C. Druce).

Early Devonian thelodont agnathan scales have been described from the basal calcareous unit of the Cravens Peak beds, also in the Toko Syncline. They are referred to Turinia australiensis, T. cf. pagei, and Gramsolepis? sp., and provide correlations with Devonian sequences in western New South Wales and the Canning Basin. They also permit some interpretation of the sedimentary environment of the lower Cravens Peak beds from their association with the ostracodes Healdianella inconstans and Baschkirina? sp., and eridostracans (Cryptophyllus sp.). The associated fauna is indicative of marine to marginal marine environments. (P.J. Jones).

DIAGENESIS (B.M. RADKE)

Study of the late diagenesis of the Cambro-Ordovician Ninmaroo Formation has produced a paragenetic sequence and model for late diagenesis, including hydrocarbon migration and sulphide mineralisation, in such epeiric sequences. The model relates diagenetic phases with erosional and tectonic events.

In the Ninmaroo Formation, after deposition and syndepositional diagenesis which included hyperactive and evaporitic overprints, the carbonates were overprinted by three additional diagenetic phases - early telogenetic (while near surface), mesogenetic (during deeper burial), and late telogenetic (during erosion after uplift).

Significant dolomitisation as well as minor hydrocarbon migration and sulphide mineralisation during mesogenetic and mixed mesogenetic-late telogenetic phases were spatially controlled by existing or active structure. During late mesogenesis, intercrystalline porosity developed from the dolomitisation while other porosity types in limestones were occluded by calcite cements or hydrocarbons. The development of moldic, collapse breccia, and cavern porosity, and karstification and dedolomitisation, occurred in both telogenetic phases but were better developed in the later, prolonged telogenetic phase.

The duration of each diagenetic phase varied locally, depending on the burial and tectonic history. Regions of differing diagenetic history are the Toko Syncline, Smoky Anticline and western platform, and the Burke River Structural Belt.

GEOCHEMISTRY (K.S. Jackson, M. Glikson, A. Hutton, J.H. Shergold, M.W. Sandstrom)

Geochemical research has continued on samples generated from the 1980 oil shale drilling program, and the earlier source rock drilling in the Toko Syncline.

Samples from BMR Coreholes Mount Isa No.1, Camooweal No. 2, Duchess No. 15A, and Tobermory No. 14 have been taken for examination using reflected light and fluorescence microscopy (A. Hutton). The biological origin of kerogens in Camooweal No. 2 is being investigated using vitrinite reflectance and electron microscope techniques. (M. Glikson).

The petroleum potential of the Toko Syncline has been re-evaluated using recently obtained geochemical data: total organic carbon calculated on a whole rock basis, total extractable matter, and liquid chromatograph separation of the extractable organic matter. Proterozoic and Ordovician formations rated poorly as source rocks in all coreholes examined. Equivalents of the Red Heart

Dolomite and Hay River Formation in Netting Fence No. 1 and the Georgina Limestone in Mount Whelan No. 1 have proved to be the most promising hydrocarbon source rock intervals. (K.S. Jackson).

A viscous oily vug filling from BMR Duchess No. 15A has been analysed, and is interpreted as an oil-stained core. The sample yielded low pristane to phytane ratios; had a limited range of n-alkanes; and had high pristane to $n.C_{17}$ and phytane to $n.C_{18}$ ratios. The oil stain either originated from marine source rocks which were mature, or the oil has been biodegraded by bacterial activity (K.S. Jackson).

Characterisation of the organic matter associated with unweathered phosphorite and siltstone in BMR Duchess No. 14 has continued throughout the year, with emphasis being placed on the kerogens and humic acid fractions. In addition to C, H, N, and organic S analyses, these fractions have been analysed for their P and $\delta^{13}C$ contents in order to interpret the source and depositional environments of the organic matter in these sediments. The presence of humic-acid carbon in the sediments indicates a very low stage of thermal maturation, and this is supported by reflectance measurements on vitrinite-like particles in the kerogen fraction which have R o of 0.2-0.4%. (M. Sandstrom).

Inorganic geochemical samples from the Hay River Formation in BMR Tobermory No. 14 have been analysed, and can be compared with values obtained from BMR Hay River Nos. 11 and 11A. These values reflect the amount of carbonate in these sequences. Higher organic carbon and sulphur can be correlated with enrichment in Mo, Th, U, Ni, Zn, and V values, and with fewer carbonate and more black shale intervals. There is a general fall off in base-metal values over more calcareous intervals of core (J.H. Shergold).

MAPS (C.J. Simpson, B.M. Radke, M.E. Freeman, J. Laurie)

A 1:250 000 special geological sheet covering the Toko Syncline and adjacent parts of the southern margin of the Georgina Basin (137-139°E, 22° 45'-23° 45'S) is in preparation. This sheet will cover all the areas from which new information has been generated in the ADAM, TOKO, ABUDDA LAKES, and MOUNT WHELAN. Additional photogeological interpretation has been undertaken in the adjacent MARQUA, MOUNT BARRINGTON, MIRRICA BORE, BARRINGTON PEAK, NEEYAMBA HILL, and GLENORMISTON areas to complete the 1:250 000 coverage (C.J. Simpson, B.M. Radke).

In conjunction with the BMR Arunta Complex Project and the Northern Territory Geological Survey, a revised edition of HUCKITTA is being prepared. DNEIPER has been completed from limited ground observation and colour airphoto-interpretation. A dyeline of the 1:100 000 preliminary geology and photo compilation sheets has already been released. JINKA and JERVOIS remain in preparation. Specific problems relating to the late Proterozoic and Cambrian geology were examined during the 1981 field season. Revised mapping of the McDONALD DOWNS, ARAPUNGA, and LUCY will be undertaken by NTGS staff in 1982.

McARTHUR BASIN PROJECT

Compiled by

K.A. Plumb, Project Co-ordinator

STAFF: K.J. Armstrong, T.H. Donnelly[1], M.J. Jackson, M.D. Muir[2], K.A. Plumb, C.J. Simpson

1. Baas Becking Geobiological Laboratory.
2. Ex BMR.

The McArthur Basin Project is a long-term project whose basic aim is to elucidate the evolution of the McArthur Basin, using stratigraphic, sedimentological, geochemical, geophysical, tectonic, and other studies, and to apply this information to the understanding of the genesis of ore deposits in the region and to the assessment of possible hydrocarbon potential of the basin.

Geological studies have been severely limited by staff restrictions; only M.J. Jackson is contributing to the project on a full-time basis. The major input to the project currently comes from the Geophysical Branch, where various sub-projects to elucidate the deep structure across the southern McArthur Basin are nearing completion; these activities are reported in the Annual Summary of the Geophysical Branch (BMR Report 238).

Present geological activity is being devoted to the completion of the research which commenced in 1977. No new work will be started by present staff until this first phase has been completed. The only fieldwork during 1981 was a short season by Jackson to confirm critical observations for completion of his sedimentological studies of the Wollogorang and Masterton Formations.

OBJECTIVES OF 1981 PROGRAM

The main objectives of the 1981 program were to:

1. Continue research on the sedimentology and palaeogeography of the Wollogorang Formation, Masterton Formation, Mallapunyah Formation, Amelia Dolomite, and related units.

2. Continue research on the sedimentology and palaeogeography of the Batten Subgroup.
3. Complete mineralogical, geochemical, stable-isotope, and fluid-inclusion studies of the Eastern Creek Pb-Ba deposit and related rocks.
4. Complete photo-interpretation and compilation of ABNER RANGE REGION.

REPORTING OF RESULTS

1. Progress of research has been reported in half-yearly reports - Records 1981/20 and 50.
2. Muir, Armstrong, & Jackson (1980) have described Precambrian hydrocarbons in the Looking Glass Formation (BMR Journal 5, 301-304).
3. Muir, Lock, & von der Borch (1980) have used detailed analogies between the Yalco Formation of the Batten Subgroup and the modern sediments in the Coorong to interpret the depositional environment of the Yalco Formation (SEPM Special Publication 28, 51-67).
4. A synthesis of the stratigraphy, structure, and evolution of the McArthur Basin is incorporated in "The Proterozoic of Northern Australia" by Plumb, Derrick, Needham, & Shaw (1981) (In: PRECAMBRIAN OF THE SOUTHERN HEMISPHERE edited by D.R. Hunter and published by Elsevier, pp. 205-307.
5. Jackson demonstrated various aspects of McArthur Group sedimentology to the Geological Society of Australia, Specialist Group in Sedimentology Meeting, Canberra, in December, 1980.
6. Jackson presented various aspects of the sedimentology of the Wollogorang Formation and its significance to syngenetic mineralisation to:
   1) Baas Becking Geobiological Laboratory Symposium, Canberra, in March 1981;
   2) CCAE School of Geology, Canberra, in April 1981;
   3) BMR Symposium, Canberra, in May 1981.
7. Jackson (1981) summarised his model for the depositional environments of the Masterton Formation, in a paper to the Fifth Australian Geological Convention, Perth, during August 1981.
8. Donnelly & Muir (1981) presented the final results of their joint study in a paper entitled "Genesis of the Eastern Creek Pb/Ba prospect and implications for some stratabound base metal deposits of northern Australia", to the Joint Meeting on Mount Isa Geology in September.
9. Plumb, Collins, Cull, Pinchin, & Zadoroznyj summarised progress on the geophysical assessment of the deep structure beneath the McArthur Basin in an abstract to the Joint Meeting on Mount Isa Geology in September.

REGIONAL STUDIES by M.J. Jackson

GEOLOGY OF THE ABNER RANGE REGION (C.J. Simpson, M.J. Jackson)

Photointerpretation and compilation of 1:25 000-scale compilations of the area to be covered by the ABNER RANGE REGION special map (Fig. S1) were completed. After checking, these preliminary 1:25 000 photoscale compilations will be issued in a BMR Record.

The northern parts of CLYDE and MALLAPUNYAH have not been remapped during the present project, so photogeological interpretation of this area was carried out with the aid of ground observations and detailed maps provided by Carpentaria Exploration Co. Pty Ltd.

MASTERTON FORMATION UNCONFORMITY (M.J. Jackson)

A significant angular unconformity has been found within sandstones previously mapped as Masterton Formation within the Batten and Tawallah Ranges (Fig. S1). This confirms a long suspected major break in sedimentation at this stratigraphic level and further justifies our intention of including the sandstone of the Masterton Formation within the McArthur Group, rather than in the underlying Tawallah Group. At three different localities several kilometres apart in the Batten Range, the unconformity surface is overlain by a 4-6 m thick massive cobble bed. This is then overlain by 200-300 m of distinctly thick-bedded mature quartz arenites. At the best exposed locality the erosive base of the cobble bed cuts across three underlying formations within a strike distance of about 500 m. These formations are:

1. a red-brown laminated hematitic siltstone (Wollogorang Formation);
2. a ferruginous, glauconitic, and quartzose sandstone sequence (Rosie and Sly Creek Sandstones); and
3. black weathering hematitic basic igneous rocks with barite (partly Settlement Creek Volcanics). These igneous rocks include both a concordant basalt stratigraphically between units 1 and 2, and an intrusive phase that has contact-metamorphosed and brecciated the siltstones of unit 1. Although quartzitic sandstone forms the most common clasts in the overlying basal cobble bed, pebbles and cobbles of these three formations can also be identified, indicating a significant stratigraphic break and extensive erosion of older rocks. The stratigraphic relationships so well exposed here confirm those interpreted in poor outcrops in the Wollogorang area, 250 km to the southeast.

One implication of this discovery is that the pre-Masterton geology shown in the Batten, Tawallah, and adjacent ranges in the BAUHINIA DOWNS and MOUNT YOUNG areas must now be revised.

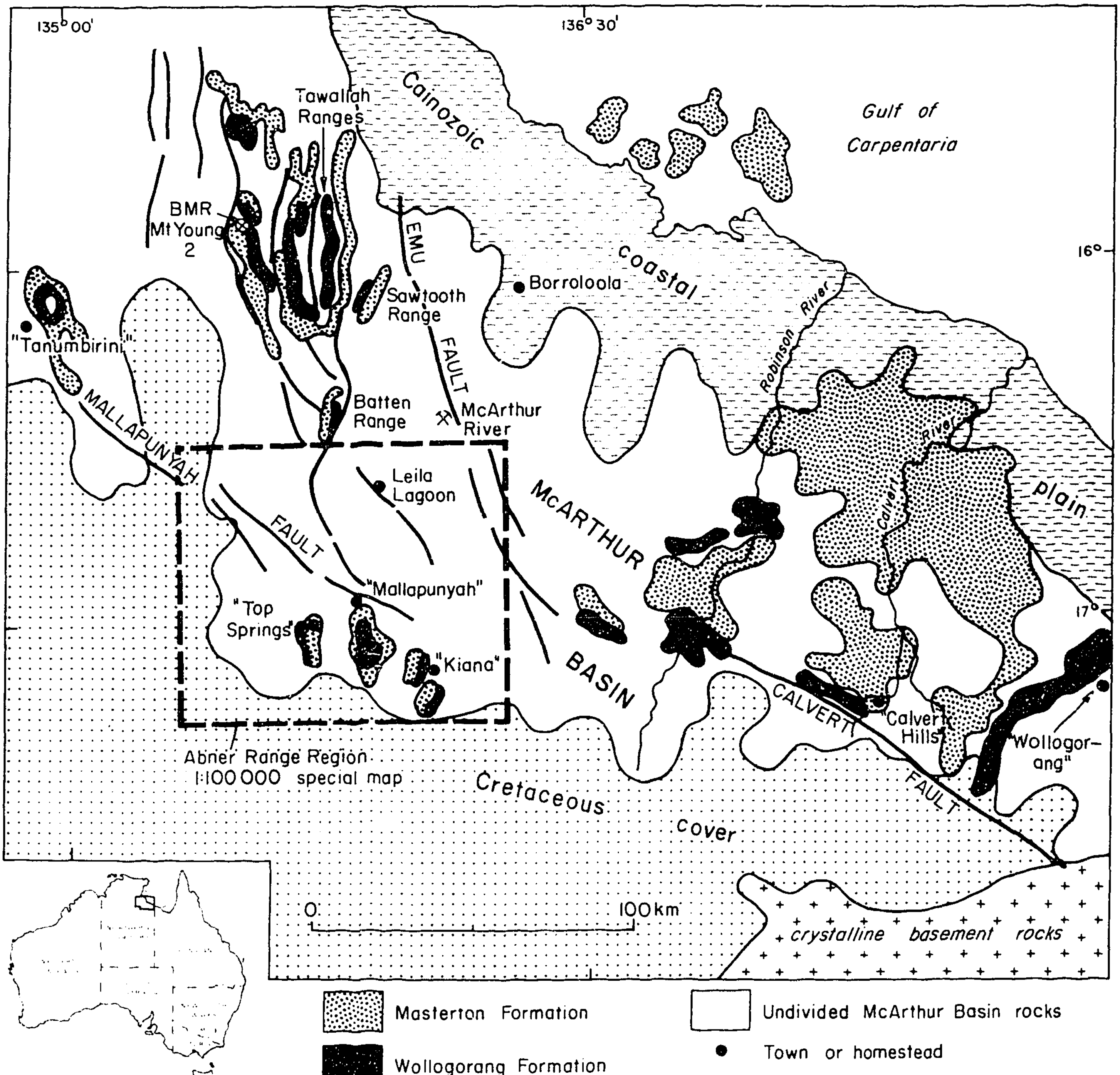

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Fig S1 Distribution of Masterton Formation and Wollogorang Formation and location of Abner Range special map

SEDIMENTOLOGICAL STUDIES by M.J. Jackson

WOLLOGORANG FORMATION

Evaporites

Detailed re-examination of measured sections in the Wollogorang area led to the discovery of two separate levels (each 4-5 m thick) of laterally persistent stratiform breccias at about the middle of the formation. Both directly overlie coarse-grained sandy dolostones containing well-preserved gypsum pseudomorphs. A mechanism of collapse, following dissolution of evaporites, seems most likely for these 'jigsaw' type breccias.

Extensive petrological work has established the former widespread occurrence of evaporites throughout the formation. Evaporite relicts were first identified in thin section from the upper part of the formation in BMR Mount Young No. 2 (Fig. S1),) where they form microscopic aggregates and veinlets of fibrous length-slow chalcedony in very fine-grained dolomitic siltstones. Larger, more complex nodules are present in thin sections of surface samples from several widely separated localities. These nodules are up to a few millimetres in diameter and comprise an outer rim of interlocking quartzite spherules, a wide zone of radially or concentrically extinguishing chalcedony, and a core of interlocking megaquartz. Remnants of anhydrite and gypsum were found in the cores of some nodules.

The presence of these widespread microscopic sulphate evaporites, the sulphate evaporite casts below the breccia beds described above, and halite casts seen in the field at three different stratigraphic levels in markedly different lithologies, indicate long-continued evaporitic conditions during deposition of the Wollogorang Formation. Many formations in the overlying McArthur Group are renowned for their evaporites, but it is now obvious that similar conditions prevailed long before the McArthur Group time.

Stromatolites

Additional field studies on the distinctive large 'beehive'-shaped stromatolite bioherms from near the base of the formation have been carried out. Some bioherms occur on the flanks of northwest-trending channels (5 m wide x 1 m deep) and lean into the channels - i.e., at right-angles to the prevailing southeasterly flowing current. Along strike, identical bioherms with similar leans have developed within horizontally bedded dolarenites lacking any evidence of channelling. At yet another locality, a similar bioherm developed from a chertified substrate containing tepee structures, suggesting growth from an originally emergent surface. All of these bioherms are restricted to one stratigraphic level, about 2 m thick. It appears, therefore, that the gross morphology was not greatly affected by the local environmental setting.

Facies

A poorly outcropping but strikingly different facies from those previously seen in the Wollogorang Formation occurs in the Batten and Tawallah Ranges. It comprises mainly iron-rich laminated siltstones with subordinate dark-weathering carbonates, and appears to lack both stromatolites and evaporites. It is tentatively identified as a quieter-energy, possibly deeper-water facies.

The detailed field analysis, together with geochemical and petrological studies, is providing a fairly well-constrained model for the depositional setting of the Wollogorang Formation. Shallow-water, probably lacustrine, evaporitic environments can be recognised in the north and south. Channel, shoreline, carbonate-bank, fluvial, and sabkha-flat subenvironments can be identified. This contrasts with a central belt of lower-energy, deeper water. The distribution of the facies suggests a depositional basin orientated west-east, in contrast to the dominant north-south tectonic elements (especially the Batten Trough) that developed later in the basin's history (during McArthur Group time).

Organic geochemistry

A suite of organic-rich, grey dolomitic siltstones from BMR Mount Young No. 2 has been sent to the University of Newcastle, England, for detailed geochemical analysis. This forms part of a postgraduate study of pre-Devonian organic material being carried out by a Ph.D. student, Mr K. Fowler. The results are not yet available.

MASTERTON FORMATION

Detailed field studies were carried out near Mallapunyah and Kiana, along the Calvert and Robinson Rivers, and in the Batten and Sawtooth Ranges (Fig. S1). A wide variety of facies is represented. In the northeast (Sawtooth Range), thick sequences of conglomerates and coarse sandstones with large-scale cross-stratification have been built up in alluvial-fan complexes. Palaeocurrent studies indicate derivation of clastic material initially from the north and northeast, but later from the west and southwest. Coarse clastics are also common in the northwest (Tanumbirini), but here they are interstratified with felsic volcanics and volcaniclastics. Debris-flow and alluvial-channel deposits containing angular blocks up to several cubic metres indicate minimal transport from a nearby volcanic upland. In contrast, the Masterton Formation in the Robinson River-Calvert River area is characterised by well-sorted, well-rounded quartz arenites and an absence of any interbedded finer units. At three different localities in this southeastern part of the basin, very large-scale cross-stratification is preserved with sets more than 15 m high; an aeolian origin is most likely. Similar well-sorted fine-grained arenites are common along the southern margin of the basin, in the Top Springs - Mallapunyah - Kiana area, but there thin siltstone interbeds and numerous siltstone intraclasts are also present. The type of cross-stratification and ripples indicate a mainly shallow-water setting.

Detailed vertical profile analysis of two 80 m-thick sections from this southern margin show an initial rapid deepening of the sea, followed by a gradual shoaling from subtidal through intertidal to supratidal sub-environments. Palaeoccurrent analysis of ripple orientations indicate three main current directions. This type of regressive sequence is interpreted as a prograding tide-dominated delta complex.

In addition to a complex depositional history, the Masterton Formation near Kiana also contains beds with intriguing conical structures. The cones are preserved in clean quartz arenites, mainly as parting surfaces, and are up to about 40 cm long. They are steep-sided (apical angle around 10^{o}), and are always orientated with their apices stratigraphically below their bases (i.e., they resemble ice-cream cones held right-way-up). They have not been found elsewhere in the basin, and do not appear to have been reported in the scientific literature. Petrological studies may aid interpretation, but some mechanism of vertical wet-sediment collapse (quicksand-like) is envisaged for their formation.

AMELIA DOLOMITE

Distinctive biohermal series of stromatolites were documented from the lower part of the Amelia Dolomite, in the Mallapunyah area. The bioherm series comprises low-relief flat-topped domes at the base, succeeded by larger columnar domal forms, and in turn succeeded by a variety of Conophyton-like stromatolites. This biohermal series is repeated several times, and probably represents repeated transgressive cycles.

KARNS DOLOMITE

Near Calvert Hills homestead, the lowermost 10 m of the Karns Dolomite contains a sequence of sedimentary structures almost identical to that seen in the lowermost 10m of the older, Wollogorang Formation: viz, wave-rippled beds, overlain by bulbous bioherms of thin columnar-branched stromatolites, overlain by oval nodular beds. The Karns Dolomite structures are preserved in a sandstone facies, whereas those in the Wollogorang Formation are in a carbonate sandstone facies, whereas those in the Wollogorang Formation are in a carbonate facies. The similarity in structures would tend to imply similar depositional settings.

Both formations were deposited on an irregular substrate after a period of emergence and erosion. However, cobble beds and cross-stratified sandstone lenses within the lower part of the Karns Dolomite indicate much stronger currents and probably a much more irregular relief than that recorded for the Wollogorang Formation.

BATTEN SUBGROUP (K.A. Plumb)

No further progress was made on the analysis of depositional environments of the Batten Subgroup during the year. Planned fieldwork was postponed until 1982.

In particular, the pseudomorphs after trona (hydrous sodium carbonate) from the Lynott Formation, tentatively reported in 1980, have not yet been confirmed. In view of the critical environmental significance (lacustrine, commonly continental rifts) of this mineral, additional samples were collected by Jackson during 1981 for thorough laboratory identification of the precursors of the present cherty pseudomorphs.

MINERALISATION (M.J. Jackson)

Wollogorang Formation

Petrological studies of thin sections from Mount Young No. 2 were carried out during the year, to complement the geochemical results reported in last year's Annual Report (BMR Report 230). The mineral occurrences are stratabound and of three types. The most common is very fine-grained pyrite, chalcopyrite, and sphalerite (few microns diameter), either evenly disseminated throughout dark grey dolomitic siltstone beds or concentrated within thin organic-rich intervals within these beds; mineralisation was obviously penecontemporaneous with sedimentation, either synsedimentary or very early diagenetic. A second type is coarse-grained pyrite and chalcopyrite (up to 2mm) rimming large nodules of pale grey coarsely recrystallised dolostone; mineralisation was later than the first variety, and occurred during the diagenetic growth of the nodules. The third variety is similarly coarse-grained, but is spatially related to evaporite minerals (now chalcedony) in pale grey silty dolostone beds, near the bottom and top of the formation, and may be of secondary origin.

Tooganinie Formation

Pods of coarse-grained copper oxides were discovered in richly evaporitic beds within the Tooganinnie Formation, and in the overlying coarse-grained cross-bedded dolomitic sandstones of the Leila Sandstone Member east of

Leila Lagoon (Fig. S1). A close relationship between evaporites and mineralisation on the one hand, and between mineralisation and coarse-grained beds on the other, is evident. Petrological and chemical studies are planned to further elucidate the relationships between the mineralisation and the sediments, but a Renfro sabkha reflux model appears attractive (Economic Geology, vol. 69, 1974).

MINERAL DEPOSIT STUDIES by T.H. Donnelly & M.D. Muir

EASTERN CREEK LEAD-BARITE STUDY

A mineralogical, geochemical, stable-isotope, and fluid-inclusion study has been carried out on samples from the following units:

1. the Kookaburra Creek Formation at the Eastern Creek Pb-Ba prospect;
2. the Bulman mine;
3. the Looking Glass Formation (Batten Subgroup) at Beetle Springs.

At Eastern Creek, barite, galena, and chalcopyrite occur at or just below the unconformity beneath the Roper Group; barite is also widespread to the west and north of the sulphide deposit. Pyrite is more widely dispersed, in minor amounts, throughout the area.

Large blade-shaped crystals of barite, with characteristic gypsum morphology, have been noted both in the Eastern Creek deposit and in surrounding sediments. The geological evidence indicates that these sediments, mainly fine-grained organic-rich dolomitic mudstones, were deposited in a shallow-water environment in which salinity increased and gypsum and halite precipitated. Vadose diagenetic alteration features are present, and the emergence of immature sediments has led to enhanced secondary porosity and permeability. The mineralisation appears to be associated with this secondary porosity.

Though the extensive sulphate accumulation in the Eastern Creek area was originally an evaporite precipitation, remobilisation has resulted in a large number of markedly discordant relationships. Later barium-containing fluids, at $\approx 150^{\circ}C$, changed the gypsum to barite without changing the $\delta^{34}S$ values. Representative samples of the barite show fairly constant $\delta^{34}S$ values (av. $+19.9^{o}/oo$), typical of isotopically homogeneous sulphate in evaporative gypsum deposits.

Except for one sample, pyrite has $\delta^{34}S$ values in the range from $+3.6$ to $+12.8^{o}/oo$, suggesting at least a component of a $\delta^{34}S$-enriched sulphur source and formation of the ore sulphides by a different process to the bulk of the pyrite. Isotopic disequilibrium between galena and chalcopyrite, and the range of $\delta^{34}S$ values, suggest that at least two pulses of a hydrothermal fluid containing Pb, Cu, and limited Fe and H_2S (HS^-), were responsible for ore sulphide deposition.

Sedimentary dolomites from the Kookaburra Creek Formation at Eastern Creek, the Looking Glass Formation at Beetle Springs, and the Balbirini Dolomite are similar in isotopic composition, and exhibit a narrow range of $\delta^{13}C$ and $\delta^{18}O$ values (av. -0.7, +21.4°/00, respectively). These values are typical for unaltered sedimentary marine dolomite of this age.

Although the mineralisation at the Bulman mine (galena-sphalerite, minor chalcopyrite, and pyrite) is different from Eastern Creek, the geological setting of the deposit, including its occurrence immediately below the Roper Group unconformity, is strikingly like that at Eastern Creek. As well, similar stromatolite-marker and oolite beds, characteristically galena-mineralised, are present in both areas. Galena, sphalerite, and pyrite from the Bulman Mine have a $\delta^{34}S$ range from +11.6 to +17.3°/oo. Whilst galena-sphalerite geothermometry indicates a depositional temperature of ca. 280°C, this may be a re-equilibration temperature due to later emplacement of adjacent dolerite sills. Pyrite is not in isotopic equilibrium with associated sulphides, a characteristic of this type of deposit throughout the McArthur-Cloncurry region.

At Beetle Springs, one drill section through the unconformity beneath the Balbirini Dolomite penetrated highly-silicified Looking Glass Formation. These originally carbonate-rich sediments are extremely vuggy and veined, and contain abundant introduced solid and liquid hydrocarbons, minor barite, saddle dolomite, pyrite, marcasite, and chalcopyrite. The sulphides analysed from the Looking Glass Formation were mainly trace pyrite plus some marcasite. Their $\delta^{34}S$ values range from -7.- to +11.0°/oo, and are more typical of sulphide from bacterial sulphate reduction.

The average $\delta^{34}S$ value of the Eastern Creek barite (+19.9°/oo) indicates the isotopic composition of sulphate of this age in the overall water body which covered the epicratonic McArthur Basin. Isotope studies of barite in the McArthur Group units elsewhere, by Walker (1980)*, tend to confirm this value. This sulphate value suggests that, on the basis of comparison with modern marine biogenic sulphide $\delta^{34}S$ distribution, pyrite associated with deposits such as the HYC, Mount Isa, and Lady Loretta has a significant hydrothermal FeS component. Similar-age Pb-Zn-Cu ore sulphides of the McArthur-Cloncurry region have similar $\delta^{34}S$ values, which in turn are similar to modern-day seafloor emanations of metal sulphides. All presently available evidence suggests temperatures of at least 200-250°C are necessary for non-bacterial sulphate reduction. Therefore it is suggested that the isotope features these deposits have in common is an argument in favour of high-

* M.Sc Thesis, James Cook University of North Queensland.

temperature origin, such as has been proposed for modern seafloor emanations, rather than in-situ low-temperature sulphate reduction.

LACHLAN FOLD BELT (CANBERRA AREA)

by

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

The Lachlan Fold Belt Project is designed to obtain a clearer understanding of the 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. Fieldwork is now complete, and work is being concentrated on finalising the Araluen and Canberra 1:100 000 geological maps and accompanying texts.

TANTANGARA-BRINDABELLA 1:100 000 SHEET AREAS (D. Wyborn)

Since completion of the 1:100 000-scale mapping in this region, follow-up studies have been carried out on the extensive sequences of Silurian volcanics.

The concept that granitoids of the Lachlan Fold Belt in southeast Australia are derived from either igneous or sedimentary source rocks (I- or S-type) can be extended to volcanic rocks of the same age. Three suites of late Silurian S-type volcanics have been recognised, two of which can be matched quite closely with plutonic equivalents. A large part of the Palaeozoic continental margin volcanic activity in southeast Australia consisted of the magmatic recycling of old metasedimentary crust, probably of late Proterozoic age. The three volcanic suites are moderately to strongly peraluminous, and contain the corresponding Al-rich minerals. Variation within the volcanic suites is ascribed chiefly to progressive removal of restite, or source material residual from partial melting.

The most mafic suite, the Hawkins Suite, contains plagioclase, cordierite, orthopyroxene, biotite, and quartz as restite components, and less abundant almandine. These rocks are chemically equivalent to mafic biotite-rich and cordierite-bearing granitoids from parts of the Berridale and Murrumbidgee Batholiths. Garnet is absent from the Goobarragandra Suite volcanics, which are a little more felsic and close in composition to granitoids of the Young and Maragle Batholiths. The S-type character of the Laidlaw Suite is less pronounced although a sedimentary source seems to be established. Such a source would be less mature than those for the other two volcanic suites. The Laidlaw Suite resembles, but cannot be closely identified with, felsic S-type granitoids of the Murrumbidgee and Berridale Batholiths.

Low-grade regional metamorphism in most of the volcanic rocks has resulted in much mineralogical alteration and mobility of alkali and alkaline earth elements. Despite this alteration, unaltered rocks are present in all three suites. Compositional data for the phenocryst phases within the unaltered rocks has allowed estimation of some intensive parameters. Hawkins Suite volcanics were extruded directly from their source region and preserve phenocryst equilibria established at 5-6 kbars and 800°C. The Laidlaw and Goobarragandra Suites re-equilibrated at lower pressures than their source before extrusion. The Laidlaw Suite re-equilibrated at estimated temperatures of 725-730°C, fO_2 of $10^{-15.5}$ to 10^{-14} bars, and $f(H_2O)$ of 2 to 2.5 kbars. Differing mineral compositions in the three suites are related to differing source rock compositions and oxygen fugacities. Relative biotite and orthopyroxene mg is possibly pressure dependent.

Mapping and mineralogical and chemical studies of an area west and northwest of Canberra have shown that the Laidlaw Volcanics are unique in the region, and that their age is tightly controlled stratigraphically as they lie both above and below Early Ludlovian (Late Silurian) fossiliferous sediments.

K-Ar mineral analyses, previously published Rb-Sr mineral analyses, and new Rb-Sr whole rock and mineral analyses together give the early Ludlovian Laidlaw Volcanics an age of 420 ± 2 m.y. However, an age of 420 m.y. for the early Ludlovian strongly conflicts with a recently published age of 421 ± 3 m.y. for the Ashgillian (Late Ordovician) Stockdale Rhyolite. The Rb-Sr isochron for the rhyolite can be interpreted as a disturbed isochron of c. 440 m.y. The age of the Laidlaw Volcanics indicate that the Silurian-Devonian boundary should be placed at no younger than 410 m.y.

ARALUEN 1:100 000 SHEET AREA (M. Owen, D. Wyborn)

Fieldwork in the area was completed in 1980 and the current year has been spent assessing the available data and compiling a First Edition map and an accompanying commentary. This work has resulted in a clarification of the relationships between various sedimentary units of Silurian age both within ARALUEN and within surrounding areas. A few days fieldwork was spent in these surrounding areas, particularly Captains Flat and the southwest corner of Braidwood, to clarify uncertain relationships.

By using correlation of sequences of facies in the Silurian successions in ARALUEN, MICHELAGO, and BRAIDWOOD it has proved possible to suggest likely correlations in the absence of diagnostic fossils. In ARALUEN, in the Shoalhaven Valley, the Silurian sequence consists of three distinct facies: a basal, transgressive shallow-marine terrigenous unit with small limestone lenses (the De Drack Formation) followed by felsic volcanics (the Long Flat Volcanics) and finally a terrigenous, flyschoid, deeper-water unit (the Palerang beds). An extremely similar sequence of facies is present at Woodlawn (the shallow-marine De Drack Formation, the Woodlawn Volcanics, and the flyschoid Covan Creek Formation) and at Captains Flat (the Copper Creek Shale, Kohinoor Volcanics, and the flyschoid Captains Flat Formation and Carwoola beds). A somewhat similar sequence is also present farther east towards Michelago, where the only difference is the presence of shallow rather than deep-marine beds (the Bransby beds) overlying the Colinton Volcanics.

We suggest that the presence of these three different facies in the same order in the Shoalhaven Valley, Woodlawn, and Captains Flat allows a correlation to be made, and that the volcanic units and hence the underlying shallow-marine and overlying deeper-marine units are of similar ages. Further we suggest that correlation with the Michelago area is also possible and that the Colinton Volcanics are the same age as the Kohinoor, Woodlawn and Long Flat Volcanics, and that the overlying shallow-marine Bransby beds are the same age as the flyschoid units in the other three areas being discussed.

Previous workers in the region have implied that there existed a meridional rift-like structure, the Captains Flat Rift Zone, through Captains Flat and Woodlawn during much of the Late Silurian. We dispute this, and suggest that all of the region was initially a shallow-marine or emergent shelf, and that, accompanying the final stages of volcanism, rapid subsidence took place from Captains Flat eastwards, resulting in the subsequent deposition of flyschoid sediments in a deep basin whose eastern margin is unknown.

The western boundary of this Late Silurian basin is considered to have been formed by a major meridional normal fault possibly immediately west of Captains Flat and Woodlawn. Sediment was transported into this basin from the shallow-marine shelf and emergent areas to the west around Michelago and Canberra. The eruption of basaltic magma accompanied the movement on this western fault (Currawang Basalt at Woodlawn and basalt flows in the Captains Flat Formation), and it is probably no coincidence that the only two major mineral deposits known from the region, at Woodlawn and Captains Flat, also lie close to this line, which is spatially related to the I-S line of Chappell & White (1974, Pacific Geology v.8, 173-174).

CANBERRA 1:100 000 SHEET AREA (R.S. Abell)

CANBERRA-YASS SHELF STRATIGRAPHY

The study has resulted in a better understanding of the Upper Silurian stratigraphic units on the Canberra-Yass Shelf. The volcanic stratigraphy in BRINDABELLA can be traced eastwards into CANBERRA and northwards towards YASS.

Walker Volcanics

The precise stratigraphic position of the Walker Volcanics remains in doubt. Based on a shelly marine fauna collected from sedimentary lenses at Coppins Crossing and Uriarra Crossing the volcanics are Wenlockian in age; they are assigned to the Hawkins Suite by the presence of garnet. The Walker Volcanics appear to be older than the Mount Painter Volcanics, which were probably deposited as one major ignimbrite eruption whose remnants now occur in synclinal folds within the Walker Volcanics. The Mount Ainslie Volcanics may be in part a lateral equivalent of the Walker Volcanics, which thicken westwards suggesting an eruptive centre in BRINDABELLA.

Colinton Volcanics

South of the Deakin Fault the stratigraphic position of the Cappanana Formation and the Colinton Volcanics is still uncertain. The mineralogy, petrology, and geochemical evidence suggests that the Colinton Volcanics have affinities with the Deakin Volcanics; the Cappanana Formation underlying the Colinton Volcanics would then be a correlative of the Yarralumla Formation. Aerial photographic interpretation of the area south of Queanbeyan indicates that the Colinton Volcanics are folded into a major synclinorium plunging SSW. At the hinge zone small outcrops of black siliceous slate of Ordovician age and limestone and shale of the Cappanana Formation reappear in the cores of minor anticlinal folds.

A palaeogeographic reconstruction proposes that at the end of the first phase of acid volcanicity (Hawkins Suite) in the Wenlockian this area was dry land. A quiescent intravolcanic phase at the beginning of the Ludlovian is indicated by a marine incursion which progressively overlapped eastwards to deposit shale, limestone, and volcaniclastic sediments on the volcanics and Ordovician rocks at the margin of the Canberra-Yass Shelf. This was followed by a second phase of acid volcanicity (Laidlaw Suite) in which the Deakin Volcanics overlapped and were disconformably? deposited on the marine sediments; it is not known if the Laidlaw Volcanics were deposited in this area. The sequence was then deformed during the early Devonian.

CAPTAINS FLAT TROUGH STRATIGRAPHY

Only a broad interpretation of the stratigraphy in the Captains Flat Trough is possible. The Carwoola beds are now considered to be younger than or in part laterally equivalent to the Captains Flat Formation, and probably correlate with local turbidite sequences exposed in the Molonglo defile and the Covan Creek Formation at the north end of Lake George. This interpretation supports the non-deposition of the Carwoola beds in the Captains Flat Syncline, and the development of a volcanogenic turbidite environment in the deeper axial portion of the Captains Flat Trough, at the cessation of Late Silurian volcanism. The age of the Carwoola beds is probably Pridolian or early Devonian.

The Captain Flat Trough is a younger tectonic unit than the Canberra-Yass Shelf. The NNW-trending Ballallaba Fault zone restricts the northward extension of the Captain Flat Trough in the vicinity of Bungendore. Northwards field mapping and drilling show that most of the bedrock beneath Lake George is probably Ordovician flysch. At the northeastern end of the lake, shallow-marine sediments and acid volcanics of the Woodlawn-Mulwaree Shelf appear; these units can be broadly correlated with sequences in the Captains Flat Trough.

TECTONICS

There appears to be evidence for four main Palaeozoic tectonic events in CANBERRA. In addition there is evidence for uplift and block faulting in the Cainozoic.

F_1 deformation (Late Ordovician/Early Silurian) - A shallow-dipping biotite foliation (F_1) suggests recumbent folding in Ordovician rocks exposed in the Cullarin and Rocky Pic Blocks. This early foliation is isoclinally folded and cut by a steeply dipping axial-plane cleavage (F_2). Rapid changes in fold facings of F_2 folds are also taken as evidence for an early F_1 deformation.

F_2 deformation (Mid-Silurian) - This event, correlated with the Quidongan deformation, produced northward and southward-plunging isoclinal folds with an intense meridional cleavage. The importance of this event is deduced largely from unconformities with variable angular discordance. An explanation has yet to be formulated for local NE-trending folds and cleavage in Ordovician and Lower Silurian inliers of the Canberra-Yass Shelf. There is now widespread recognition of the Quidongan deformation on the Canberra-Yass Shelf and across the Cullarin Block; its further extension eastwards needs evaluation.

Recent isotopic dating of the Sutton acid intrusive complex implies that this deformation was completed before 410 m.y. A contact metamorphic zone associated with this complex postdates F_2 folds; accommodation folds are displayed by a flattening of dips and a gradual displacement west of meridional F_2 fold axes around the southern margin of this intrusive complex.

F_3 deformation (Early to Middle Devonian) - This deformation is demonstrated by mild northeast-trending open folds which grade eastwards into tighter folds with an intense cleavage foliation at the eastern margin of the Canberra-Yass Shelf. East of the Cullarin Block, folding and foliation associated with this deformation have not been recognised, and it appears that this deformation was no more than a mild phase of warping and faulting.

F_4 deformation (Late Devonian/Early Carboniferous) - In the Captains Flat Trough this deformation is represented by meridional variably plunging isoclinal folds, reverse faults, and conjugate kink or crenulation tectonics. Some evidence for the age of this folding is afforded by the foliated Gourock Granodiorite, which has been dated as 373 m.y. The westward extent of this deformation in the Captains Flat Trough is probably limited by the Lake George-Whiskers fault zone. In the Canberra-Yass Shelf this deformation was milder and denoted by complex conjugate faulting. Lateral displacement along some of the NE and NW-trending faults also formed similarly trending large-scale kink folds.

Cainozoic uplift Two periods of Cainozoic faulting are recognised along the Lake George Fault line scarp. A meridional trending portion of the scarp dying out southwards towards Primrose Creek has a mature relief and drainage pattern, and represents a remnant of an early period of Tertiary movement. A youthful NNW-trending section of the scarp in the vicinity of Lake George which has disrupted part of the drainage pattern of the upper Yass River catchment represents fault-line rejuvenation during the Late Tertiary. Similar NNW-trending scarps occur along sections of the Murrumbidgee and Queanbeyan fault lines. Seismic epicentres detected in the Gunning area between 1958-61 are closely aligned with this Late Tertiary trend.

ACID INTRUSIONS

Small discontinuous foliated quartz-feldspar bodies and granitoids are exposed as meridionally trending slightly discordant intrusives in Ordovician flysch in the Cullarin and Rock Pic Blocks. These acid porphyries were probably intruded during the F_2 deformation as their foliation parallels the F_2 cleavage in the country rocks.

With the exception of the S-type Murrumbidgee Batholith, the Siluro-Devonian granitoid intrusives and high-level quartz-feldspar porphyries fall into the I-type group which youngs from west to east.

Acid porphyry dykes at the eastern edge of the Cullarin Block may represent feeders for acid volcanism that developed at the rift margin of the Captains Flat Trough; they are locally mylonitised within the Lake George-Whiskers fault zone.

BASIC INTRUSIONS

Non-alkaline basic intrusive activity is associated with crustal rifting in the east of the Sheet area. An early phase of basic intrusion is indicated by folded and foliated epidiorite bodies at the north end of Lake George, foliated gabbros and amphibolites of the Lockhart Complex, and possibly meridionally trending dolerites along the western margin of the Captains Flat Trough. A younger suite of dolerite dykes trends northwest and cuts across the Lockhart Complex and most acid intrusive rocks activity dies out westwards. In the Captains Flat Trough an older age limit for these basic intrusions is constrained by the Currawang Basalt (Late Silurian) which is cut by early-phase intrusives. A younger age limit is provided by the F_4 deformation which foliates all the basic rocks including the younger suite of northwest-trending dykes.

A few basic dykes with alkaline affinities which may be Mesozoic or Tertiary occur in the west of the Sheet area.

NORTH VICTORIA LAND, ANTARCTICA

by Doone Wyborn

During 1981, laboratory studies have been carried out on rocks collected in 1980. Geochemical work has concentrated on the granitoids and the sediments of the upper Precambrian Robertson Bay Group.

The subdivision of granitoids in north Victoria Land into two groups (1) Devonian Admiralty Intrusives and (2) Cambro-Ordovician Granite Harbour Intrusives, has been confirmed for plutons sampled during the 1979-80 Federal German Antarctic North Victoria Land Expedition (GANOVEX 79). All plutons east of the Bowers Tectonic Zone are grouped as Admiralty Intrusives. They are high level, intensely discordant and have the petrographic characteristics of I-type granitoids. Several newly discovered plutons were mapped, including the Yule Batholith, a complex of about 1600 km^2 in the Yule Bay area. Most Admiralty Intrusives are biotite granites commonly carrying hornblende, with colour indexes up to 20. More mafic hornblende-biotite granodiorites are rare.

Both S-type and I-type granitoids are represented in the Granite Harbour Intrusives from the west of the Bowers Tectonic Zone. S-type granitoids are the more common. They occur in the Daniels Range, where they are locally derived from metamorphosed rocks of similar composition to the Robertson Bay Group. They are also present in the Morozumi Range and Renirie Rocks, where they have migrated from the anatectic zone. The most common rock types are biotite and two-mica granites and granodiorites with colour indexes rarely exceeding 15; a cordierite-bearing granite was sampled from the Daniels Range. I-type Granite Harbour Intrusives are not common. They are mostly hornblende-biotite tonalites with colour indexes of 30 or more, but one heterogeneous pluton from the northern Lanterman Range is dominantly lighter hornblende-bearing biotite granite.

Thirty-seven granitoids and 57 sediments have been analysed for major and 20 trace elements. In September 1981 a lecture was given at the BGR, West Germany, on the results of these geochemical studies. Two suites of I-type granitoids are recognised in the Admiralty Intrusives: one with high Na, Ca, Sr, and the other with high K, Rb, La, Ce, Nd. The S-type Granite Harbour Intrusives are derived from a more feldspathic source than most SE Australian S-type granitoids. They are consequently higher in Na, Ca, and Sr. Robertson Bay Group sediments associated with these granitoids are also enriched in Na, Ca, and Sr relative to modelled source compositions of SE Australian S-type granitoids. However, Robertson Bay Group sediments east of the Bowers Tectonic Zone are lower in Na and Sr than those to the west associated with the Granite Harbour Intrusives, and closely resemble modelled SE Australian S-type granitoid source rocks. Robertson Bay Group sediments are enriched in Cr and Ni adjacent to mafic volcanics of the Bowers Tectonic Zone (Glasgow Volcanics), suggesting a detrital input from the volcanics and a similar age. The volcanics were thought to be younger by previous workers.

AUSTRALIA-WIDE STUDIES

PERIOD STUDIES

by

W.J. Perry

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

This pilot study of the Oligocene Epoch in Australia aims to arrive at a satisfactory method of studying a geological period Australia-wide; the project is a part-time activity. Progress is as follows:

Gippsland Basin - compilation of 1:500 000 structure contour maps on top and base of Oligocene rocks, 1:500 000 isopach map of Oligocene, and a draft 1:2.5-million-scale reduction of the isopach map. In the northeast of the basin the Oligocene rocks generally range in thickness from a few metres to 100; in the west and centre they are thicker, ranging up to 300 m, and the thickest development, more than 450 m, is in the eastern central part.

Bass Basin - compilation of 1:500 000 structure contour map on the base of Oligocene rocks, 1:500 000 isopach map of Oligocene, and a draft 1:2.5-million-scale reduction of the isopach map. The isopachs are roughly parallel to the structure contours on the top of the Cretaceous to Eocene Eastern View Group. The thickest development of Oligocene rocks, more than 450 m, is near the centre of the basin.

Murray Basin - data from petroleum exploration wells coded and entered into Image data base.

Northwest Australia - data from three offshore petroleum exploration wells coded and entered into Image data base.

HYDROGEOLOGICAL STUDIES

MURRAY BASIN

by

C.M. Brown

STAFF: C.M. Brown, A.E. Stephenson (from June, 1981), P.E. O'Brien (part time), M.A. Habermehl (part time) W.J. Perry (part time).

The objectives of the Murray Basin hydrogeological project are to collect, analyse, and interpret geological and hydrogeological data in order to develop and apply a model which, if feasible, can be used to simulate the groundwater hydrodynamics of the Murray Basin as an aid to the management of its groundwater resources. The project is being undertaken jointly with the South Australian, Victorian, and New South Wales geological surveys and water authorities and is co-ordinated by a Steering Committee comprising members of participating organisations. The primary aim is to improve the understanding of the groundwater regime of the basin by examining it as a single entity unencumbered by State boundaries.

GEOLOGICAL SYNTHESIS

The project has been organised into a number of phases. Since a knowledge of the geology of the basin is fundamental to the understanding of groundwater occurrence, the first and current phase comprises a geological synthesis using all available geological and geophysical data and includes a review of older intrabasins underlying the Cainozoic Murray Basin and an assessment of other mineral resources. In BMR, work has mainly concerned documentation of the regional distribution, depositional environment, geometry, and porosity and permeability characteristics of the major aquifer systems of the basin. In particular the apparently close correlation between the Cainozoic stratigraphic sequence of the Murray Basin and global cycles of relative change in sea level is currently being investigated, and may help to further an understanding of the complex intercalations of fluviolacustrine, paralic and shallow-marine depositional sequences which occupy the basin.

Borehole locality maps of tabulation of down-hole stratigraphic and aquifer data have been completed for sixteen 1:250 000 Sheet areas. Work commenced on a compilation of subsurface geology of western New South Wales, which was undertaken jointly with the Water Resources Commission of New South Wales. Examination of several hundred drillers' logs allowed stratigraphic units from the northern South Australian sector of the basin to be correlated with units in northern Victoria. In particular, the 'Morgan/Mannum equivalents' and 'Pata equivalents' of South Australia appear to correlate respectively with the Winnambool Formation and Geera Clay in Victoria. The Winnambool Formation also appears to be a laterally continuous, but diachronous, equivalent of the lithologically similar Ettrick Formation of South Australia and the Ettrick Marl of Victoria. Revision of stratigraphic relationships suggests that open-marine-shelf calcarenites of the Morgan Limestone/Mannum Formation/Pata Limestone/Duddo Limestone are partly enveloped to the north and east by restricted marine-shelf and lagoonal marls of the Winnambool Formation, in turn partly enveloped by restricted lagoonal and tidal-flat terrigenous clastics of the Geera Clay, which is further partly enveloped by fluviodeltaic sediments of the Olney Formation.

Examination of digitally enhanced Landsat scenes and small-scale aerial photography over the South Australian and adjacent Victorian parts of the basin by W.J. Perry in conjunction with compilation of subsurface data by C.M. Brown and A.E. Stephenson indicates that former strand-lines and beach ridges of the Pliocene aquifer system are more extensive than previously thought. Copies of a 1:1 000 000-scale Landsat mosaic and computer printouts of the Murray Basin bibliographic data base were distributed to participating organisations.

Work continued on the compilation of a 1:1 000 000-scale geological map of the Murray Basin and a 1:1 000 000 Bouguer gravity anomaly map illustrating infrabasin and basement structural trends beneath the Murray Basin. In addition, preliminary subsurface structure contour maps depicting the geometry of the Renmark Group, Murray Group, and Pliocene sand aquifer systems were completed and despatched to counterparts in the Engineering and Water Supply Commission of South Australia and the Geological Survey of Victoria for the purpose of preliminary groundwater modelling. Drafting of a Murray Basin contribution to the ESCAP Atlas of Stratigraphy was also completed.

Brown, Habermehl, and Stephenson, together with counterpart workers from the South Australian and Victorian Geological Surveys and the Water Resources Commission of New South Wales, visited various localities in the basin from 5-15 October with the principal objective of achieving a greater understanding of stratigraphic problems encountered in the geological synthesis.

Data sheets were designed and explanatory notes written for use in the transcription of geological and hydrological data from State authority records into the Murray Basin hydrogeological data base system, which is to be implemented on the BMR computer. The data base is designed to accommodate hydrogeological data from the Murray Basin and the ACT, but is general enough to be suitable for all groundwater basins. Familiarisation with Murray Basin hydrogeological data continued, and data availability was investigated.

BROWN COAL

A talk on Tertiary brown coal deposits in the Murray Basin was presented at the Coal Workshop session of the CECSEA Conference held in Canberra in late November 1980. The talk described the distribution of brown coal in New South Wales and Victoria and discussed the relationship between the accumulation of coal-bearing sediments of the Murray Basin and global cycles of relative rise in sea level. The coals occur as discontinuous lenses within paralic and fluviolacustrine sediments of the upper Eocene to lower Oligocene upper Renmark beds (South Australia) and their equivalents, the upper Eocene to mid-Miocene Olney Formation of the Renmark Group (Victoria and New South Wales). In the east the coals occur beneath an overburden of between 80 and 130 m, whereas to the west they occur at depths of as much as 300 m. They are of low rank, having undergone varying degrees of coalification, and range from peat through soft brown coal to dull black lignite. They mainly show the characteristics of peaty coals deposited in swamp and marsh environments, and grade laterally and vertically into carbonaceous clays and marls. Minor woody coals, presumably from fringing forest environments are intercalated with channel conglomerates and sands. Limited analyses indicate that they have a low calorific value, high moisture, and variable ash and sulphur contents. The stratigraphy of the Murray Basin can be correlated with global cycles of relative change in sea-level which resulted in regional disconformities and laterally extensive and complex migrations of facies boundaries. Enhanced peat accumulation in the Murray Basin was mainly confined to the period late Eocene to mid-Miocene, and increased during periods of relative rise in sea level when crustal subsidence and sediment compaction were favourably balanced against rate of sedimentation.

DEVONIAN INFRABASINS

A paper on the source rock potential and hydrocarbon prospectivity of Lower Devonian sediments in concealed graben-like troughs of the western Darling Basin beneath the northern Murray Basin, based on a geochemical study of core and cutting samples, was completed in conjunction with co-authors in the Petroleum Exploration Branch, BMR. The main conclusions reached are that the Lower Devonian marine sequence has a low organic carbon content, is probably gas prone, is thermally mature to overmature within the graben-like troughs, and is downgraded as a potential hydrocarbon source rock. Potential source and reservoir rocks are only likely to be preserved on trough flanks or margins which have not been deeply buried or tectonically deformed during Devonian-Carboniferous periods of folding, faulting, and rifting.

PERMIAN INFRABASINS (P.E. O'Brien)

Permian sediments are present in eleven sub-basins beneath the Cainozoic Murray Basin sequence. Two distinct stratigraphic units are present: a Lower Permian marine sequence, which is overlain beneath the eastern part of the Murray Basin by the Upper Permian Coorabin Coal Measures. The literature on these sediments was reviewed and bore material studied to elucidate the sedimentology of the Lower Permian sediments and to reassess their hydrocarbon and groundwater potential.

The Lower Permian marine sediments contain an Early Permian microflora and a restricted assemblage of arenaceous and calcareous foraminifera. Cores from petroleum exploration wells that intersected this unit contain a number of facies, some of which are recognisably glaciomarine sediments. The facies are:

1. diamictites consisting of siltstone or claystone plus ice-rafted sand and pebbles;

2. massive diamictites probably deposited by debris flows derived from other glacial or glaciomarine sediments;
3. massive siltstones with small amounts of ice-rafted sand;
4. interbedded claystones and graded siltstones deposited during periods of intermittent current activity;
5. massive coarse and fine-grained sandstones and fine-grained ripple cross-bedded sandstones of which some may be deltaic sediments;
6. sandy boulder conglomerates.

Palynological reports indicate that some of these sediments were deposited at the same time as tillites in central Victoria, whereas some are younger and contain facies assemblages which record the waning of the late Palaeozoic glaciation of southeastern Australia.

The evidence presently available suggests that the hydrocarbon potential of these lower Palaeozoic glaciomarine sediments is low because they are poor in organic matter. Also, sandstone facies which might form reservoirs are usually clayey and hence impermeable. These rocks contain saline groundwater, but it does not seem to interact with the overlying Cainozoic aquifers.

GREAT ARTESIAN BASIN

by

M.A. Habermehl

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

The Great Artesian Basin (GAB) project which consisted of a hydrogeological study of the multi-aquifer confined groundwater basin, and the development and application of a mathematical, computer-based model to simulate the groundwater hydrodynamics, was finalised and reported on during 1980. Hydrochemistry and isotope hydrology studies in the GAB continued during 1981 as part of the investigations for the regional assessment of the basin's artesian groundwater resources, the results of which can be used for planning and management purposes, and for assessment of mineral and/or petroleum resources.

Chemical analyses of water samples taken during the wire-line logging of water wells in the GAB by BMR from 1960 to 1975, of samples obtained from wells sampled for environmental isotopes by the Australian Atomic Energy Commission and BMR from 1974 to 1979, and of samples obtained by BMR in the Central Eromanga Basin in 1980, and data from wells and springs in the southwestern part of the GAB, were interpreted. Multivariant statistical computer analysis of the chemical data led to group classifications which were used to interpret hydrochemical facies. Groups subdivided by statistical means not only reflect different regional origin, but also different aquifers. Additional information was also obtained on regional groundwater flow patterns, independent of the model simulation results of the groundwater hydrodynamics.

Documentation of some aspects of the regional groundwater flow patterns started in the southwestern part of the GAB. Compilation of data from the central part of the GAB (Central Eromanga Basin area) continued, including hydrogeological, hydrochemical, and hydrocarbon analysis results, which will be used to define the hydrodynamic and hydrochemical character of that part of the basin and to assist in the study of possible hydrocarbon migration and st..nation near structural and stratigraphic traps. Preliminary analysis results by the BMR Petroleum Technology Laboratory indicate the presence of methane, carbon dioxide, nitrogen, and traces of hydrocarbons of the paraffin series in the samples obtained from water wells in the Central Eromanga Basin area during 1980. Discussion continued during the year with the Geological Surveys of Queensland and South Australia and petroleum exploration industry geologists on aspects of the GAB/Eromanga Basin.

Compilation continued of BMR hydrogeological data and of results from the analyses carried out by AAEC of naturally occurring isotopes in the GAB. The isotope hydrology study of the GAB which is jointly carried out by AAEC and BMR is aimed to provide qualitative and quantitative information complementary to data obtained by conventional hydrological techniques, and to provide an independent check on derived hydraulic data. The residence time and rate of flow of the groundwater through the aquifers can be estimated and its origin elucidated. In addition valuable information on the chemistry of the groundwater and the aquifers, and on the possible transport of minerals and hydrocarbons by the groundwater is obtained.

A planned field trip to sample flowing artesian water wells in the GAB for the long-lived isotope ^{36}Cl which would be more suitable to date the very old groundwater in parts of the basin further away from the recharge areas was deferred to 1982.

A map at scale 1:2 500 000 showing the location and registered numbers of wire-line logged water wells in the GAB was finalised and released in 1981. The Report 'Index of geophysical well logs acquired by BMR from water wells in the Great Artesian Basin 1960-1975' by Habermehl and Morrissey, which lists all well and log data from the wells logged is awaiting computer processing of the stored data before it can be completed. Master copies of paperprints of all logs (natural gamma-ray, neutron, temperature, differential temperature, casing-collar locator, flow-meter, spontaneous potential, resistivity, caliper wire-line logs and drillers lithology logs) at 1 inch to 100 feet scale were maintained as well as the original transparencies of the logs produced by BMR, which are used to produce copies of logs requested by visitors, industry, and State authorities. Alternative storage facilities for the log originals were investigated.

A draft paper on the GAB was prepared for the textbook on Earth sciences for Australian high schools, which is being prepared by the School Geology Project of the Australian Academy of Science. It is to be used as a separate section within the water chapter (author D.N. Body, CSIRO).

Comments on hydrogeological aspects of the Final Environmental Impact Statement of the Honeymoon Uranium Project for the Department of Home Affairs and the Environment were prepared as a Professional Opinion with D.J. Perkin.

Meetings of the Organising Committee of the AWRC Conference on Groundwater in Fractured Rock, to be held at Canberra in 1982, were attended. Habermehl, as Papers Secretary, organised the Call for Papers, received and assessed the synopses of papers, and prepared proposals for their provisional acceptance.

NORFOLK ISLAND GROUNDWATER

by

R.S. Abell

At the request of the Department of Housing and Construction (NSW region) and the Norfolk Island Administration, a BMR survey team conducted hydrogeological and geophysical investigations on the island in mid-1981. The main objectives of the survey were to provide drill sites and advise on a drilling program in the Broken Bridge-Mission Creek catchment to test whether a deep potable groundwater supply can be developed from bedrock aquifers as an alternative to the locally polluted shallow groundwater currently exploited from perched aquifers in weathered volcanic rocks.

GEOLOGY

Norfolk Island has an area of 35 km^2. It is an erosional remnant of a volcanic complex on the mainly submarine Norfolk Rise which extends from New Zealand to New Caledonia. The deeper-lying unweathered part of the volcanic sequence is made up of relatively flat-lying interbedded basaltic lava and tuff. Along the shore of the Kingston lowland are flaggy calcareous aeolianites. On the northern side of the island hyaloclastites (breccias) and hackly jointed lava are exposed close to sea level. These autoclastic rocks which are thought to underlie the island are products of the fragmentation of subaerial lavas as they flowed into the sea. A deep-weathering profile up to 50 m thick has developed in the volcanic succession since eruptive activity ceased during the late Pliocene 2.3 m.y. ago.

HYDROGEOLOGY

The hydrogeological model proposed for Norfolk Island is a two-component groundwater storage system connected by fractures (see Fig. S2).

The upper storage is a perched water-table aquifer in the porous weathered mantle having considerable groundwater storage capacity. This is the main aquifer presently exploited, but it is currently threatened in the short term by pollution arising out of effluent from septic tanks and other domestic and livestock waste.

The lower storage is thought to be a basal groundwater aquifer in hyaloclastic rocks at and below sea level and as yet unexploited. Evidence that these rocks have potential as an aquifer is afforded by the occurrence of seepage zones particularly in coastal exposure around the northwest plateau and field observations, petrographic examination, and laboratory analyses which show these rocks to have a porosity and permeability framework capable of retaining basal groundwater.

An intermediate hydrogeologic zone connects the upper groundwater storage in the weathered mantle and the lower groundwater storage in hyaloclastic rocks. Recharge to the basal aquifer is accomplished through this zone by vertical groundwater leakage from the weathered mantle into a complex distribution of fractures in unweathered basaltic lava. Where vertically migrating groundwater occurs in basaltic tuff beds in this zone, recently drilled water-bores indicate that the system behaves as a semiconfined aquifer with the potential to yield groundwater supplies between the weathered mantle and basal aquifer.

The permeability distribution in hyaloclastic rocks and pillow lavas underlying Norfolk Island is poorly known. Basal groundwater in this model (Fig. S2) is depicted as occurring in permeable pockets sealed by impermeable rock, or in fractures. This anisotropic permeability distribution on Norfolk Island suggests that the classical geometrical lens shape of a freshwater body is likely to be distorted into a complex interfingering shape. The zone of mixing between freshwater and seawater will be greater along zones such as fractures and permeable pockets than intervening impermable pockets. While it is evident that the upper groundwater storage feeds and recharges the lower groundwater storage by gravity flow through fractures, recharge maybe cut off

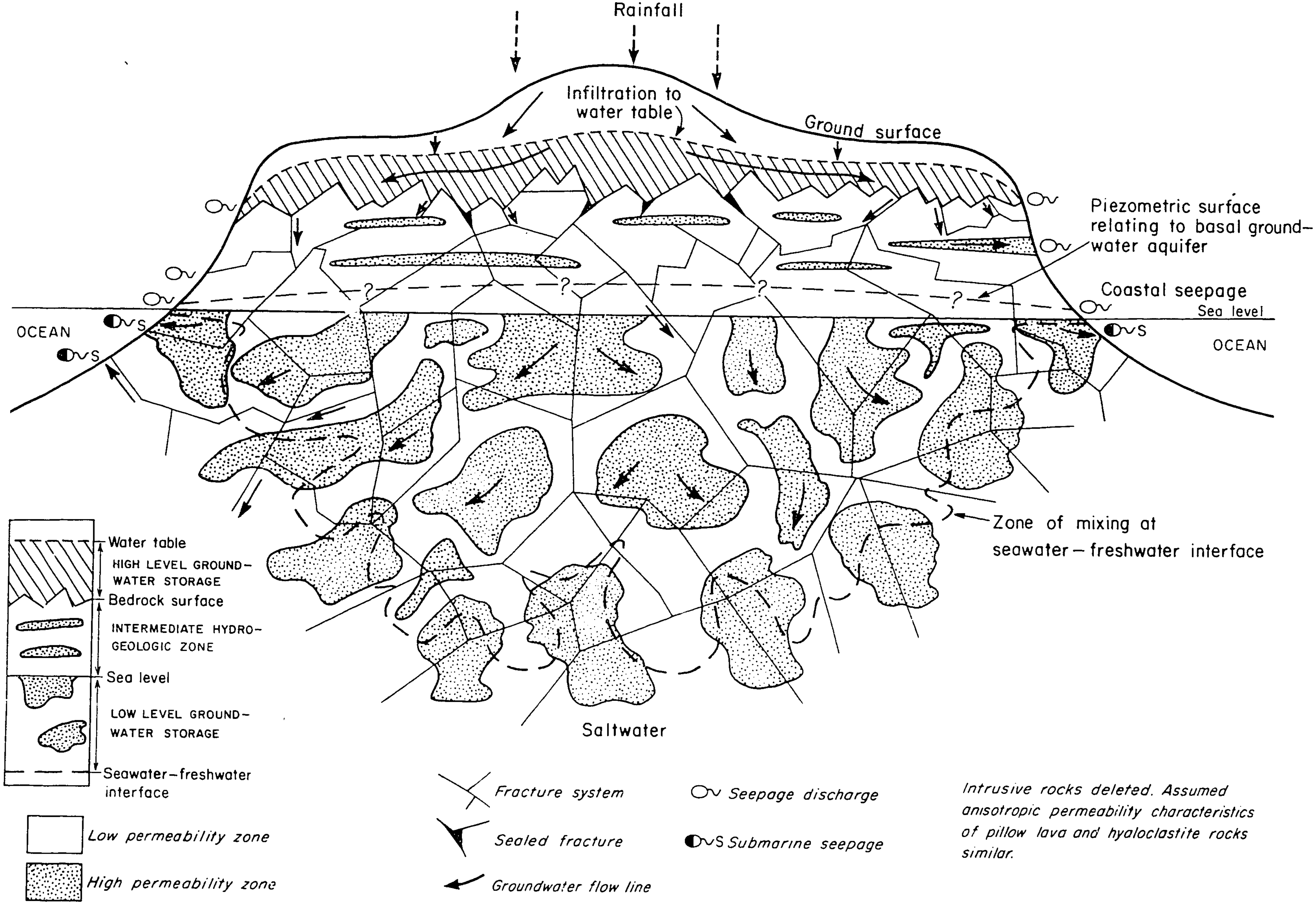

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Fig. S2 Simplified groundwater model for Norfolk Island

19/09/77

locally and dry permeable pockets in bedrock may form where deep weathering has penetrated sufficiently to clay-seal fractures.

The quality of the groundwater in the bedrock aquifers is expected to be suitable for domestic use and substantially better than the groundwater currently extracted from the weathered mantle.

GEOPHYSICS

The resistivity survey in the Broken Bridge-Mission Creek area was successful in providing information on prospects for the occurrence of shallow groundwater. Low-resistivity values indicate zones of saturated deep weathering which, if coincident with fractures, may provide sources of shallow groundwater which contribute to the recharge of deeper aquifers. The hydrogeophysical response of bedrock was hampered in the investigation area by the dissected topography which restricted the electrode spacing that could be used for Wenner profiling and depth probes. The interpretation of resistivity results was limited by the low-resistivity contrasts that characterise the volcanic sequence; however, on the Kingston lowland a depth probe confirmed the existence of saltwater at a depth of 17 m with an overlying zone of brackish water 15 m thick.

On the results of the resitivity data four drilling sites were selected.

Magnetic field intensity data were measured along the same survey lines as used for resistivity. The recorded total magnetic field is typical of a basaltic lava and tuff sequence. The high noise levels in the profiles are due to variations in remnant magnetism and other magnetic inhomogeneities in the rock sequence rather than man-made interference (metal, powerlines, etc.). The attenuation of the magnetic intensity profiles along Mission Creek and at Kingston maybe due to poorly magnetic alluvium or calcareous aeolianite overlying a local thickening of the weathered volcanic profile. This reconnaissance magnetic data was unsuitable for the selection of drill sites.

RAINWATER QUALITY

From 1978-80 rainwater samples were collected on Norfolk Island to assess quality and cyclic salt concentrations. Interpretation of the data shows that (a) rainwater i[illegible] weak solution of NaCl having a similar SO_4:Cl ratio to seawater; [illegible] ihere appears to be little correlation between rainwater salinity and climatic data; the range of chloride in the rainwater samples probably depends on the time elapsed between rainstorms, the amount of rain, wind, surf conditions, and the elevation and position of the sampling site relative to sea level; (c) the chemistry and low-salinity values (not exceeding

63 micromhos/cm) are typical of rainwater collected in an oceanic environment far removed from continental influences and pollution sources; the analyses provide a useful set of data that may find comparative use with other island environments in the Southwest Pacific;(d) in the Burnt Pine-Middlegate area groundwater recharge to the weathered mantle is estimated at 17.7% of annual rainfall based on an evapotranspiration related concentration process using the ratio of chloride ions in rainwater and shallow groundwater; this estimate does not represent a direct recharge value to basal aquifers since groundwater losses from the weathered mantle occur as baseflow along creeks and coastal seepages at the perimeters of the island.

PHOTOGEOLOGY AND REMOTE SENSING

by

C.J. Simpson

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

FIELD RESEARCH

Simpson assisted both the McArthur Basin and the Georgina Basin Projects (see under those project headings).

REMOTE SENSING (Landsat)

During the year the Sub-Section acquired a Comtal Vision One/20 digital image analysis system primarily for research into geological applications of Landsat digital data. After some initial system problems the unit is now functioning satisfactorily. Programming of the system for BMR needs is expected to take at least another year. During that time the effectiveness of Landsat analysis in assisting with field party problems will be evaluated. Investigations have been initiated into specific problems in the Litchfield Province (rock differentiation), Toolebuc Limestone (distribution mapping), and Karkar volcano (eruption damage). Preliminary applications of the system for other digital data manipulation such as the display of digital aeromagnetic and topographic information in image form suggest considerable promise for assisting geological studies.

To assist research and general usage of Landsat a microfiche image catalogue viewing system was established, together with new ordering procedures for data products from the Australian Landsat Station. The fiche image catalogue under the auspices of D. Park contains all images acquired by Landsat over Australia since December 1979. Images of Irian Jaya and PNG will be added as they become available

Members of the Sub-Section had various discussions with staff from the Australian Landsat Station to assist them with problems of product quality control.

Simpson presented an invited paper "Landsat remote sensing in the search for mineral and petroleum resources" to the 51st ANZAAS Congress in May in Brisbane. Perry was a member of the organising committee for the Landsat 81 Conference held in Canberra from 1-4 September, and members of the Sub-Section participated in a workshop preceding the conference on 31 August. Simpson presented a session on Landsat interpretation for geology. Perry assisted in the preparation of the Workshop Notes and delivered a lecture "Characteristics of the Landsat system", and Moore a lecture "Digital image processing systems". Two papers; "Landsat digital image analysis in BMR regional geological investigations" (Simpson), and "DIPORS: a bibliographic data base for digital image processing of remotely sensed data" (Moore) were presented during formal sessions of the conference.

At the 10th BMR Symposium, Moore delivered a paper "LANDSAT for BMR - present and future applications". From 8-11 September he attended the Australasian Symposium on Stereology, Image Analysis and Mathematical Morphology, in Sydney.

Simpson presented an invited lecture "Landsat in petroleum exploration" at the June meeting in Melbourne of the Victorian and Tasmanian branches of PESA.

TRAINING

Members of the Group assisted with both internal and external training courses on remote sensing.

Moore presented a special introductory course on the BMR digital image analysis system. Five external visitors from private companies (CRA, CSR) who have identical systems also attended.

Perry and Simpson, with assistance from lecturers from CSIRO and Industry, presented the course "Geological interpretation of aerial photographs and satellite images" at the Australian Mineral Foundation, Adelaide, 1-12 December 1980, and 21-28 February 1981.

Simpson and Moore delivered lectures to a special Landsat workshop held at CCAE 16-20 February, and Simpson assisted with a special one-day seminar "Introduction to Remote Sensing" in Adelaide 15 May, arranged by the South Australian Committee on Remote Sensing in conjunction with the South Australian Institute of Technology.

MARINE GEOLOGY

EASTERN SHELF MINERAL SANDS STUDY

by H.A. Jones

STAFF: H.A. Jones, J.B. Colwell, P.J. Davies, M.H. Tratt, T.W. Brown, T. Hegvold, G. Price

Sonne cruise SO-15 on the east Australian continental shelf was undertaken to investigate the stratigraphy and depositional environments of the superficial sediments of the inner shelf, and particularly to establish the distribution of heavy minerals in the offshore sequences and the factors controlling placer formation. The cruise took place within the framework of the West German-Australian Science and Technology Agreement and made use of R/V *Sonne*, one of the most advanced general-purpose ocean-going research vessels in the world, chartered by the FRG Ministry of Science and Technology and operated by the West German Federal Geological Survey (BGR).

Sonne carried a scientific complement of 22 during most of the cruise, which lasted from 20 September to 20 November 1980. The German party formed about half this number, and included a scientist from Aachen Technical College and two representatives from Preussag A.G. BMR had five men on board throughout (two geologists, one geological technical officer, one electronics technical officer and one draughtsman), and the Australian Survey Office provided two surveyors who operated the Decca Trisponder navigation system used for accurate positioning of the ship. The Geological Surveys of Queensland and New South Wales each provided 2 or 3 staff while the ship was operating off the coast of their respective States, and a representative of CRA Ltd was on board when the ship was in southern Queensland waters where that company holds an Authority to Prospect for minerals. The cruise leader was Dr U. von Stackelberg of BGR.

Analysis and reporting of results, which are still in progress, are the joint responsibility of BGR, BMR, and the Queensland and NSW Geological Surveys. The first comprehensive publication of the results of the cruise will be in English in the German Journal Geologisches Jahrbuch in mid-1982.

Methods

The cruise was split up into four legs, each consisting of a seismic profiling operation followed by geological sampling. The areas covered (Fig. S3) extended for a combined linear distance of about 450 km. A total of 2590 km of seismic profiles was collected and 815 sampling stations were occupied.

Seismic profiling was carried out with a 165 cm^3 airgun and single-channel streamer, and a 3.5 kHz pinger; analogue recordings were made at 0.5 s and 0.25 s sweep rate. A number of short sidescan sonar and T/V-scanning runs were also made.

At most of the 815 sampling stations surface samples were recovered with a Van Veen grab. A small number of surface samples was also collected with a Shipek grab as an underway sampler, or using a chainbag dredge. A total of 391 m of core was drilled at 110 stations using either a Geodoff vibrocorer (maximum penetration 9.5 m) or a Kiel vibrocorer (maximum penetration 4 m). An additional 242 m of subsurface samples were recovered with the Geodoff drill in the counter-flush mode, in which the recovered sample is in the form of an aerated slurry.

Sample treatment on board included sieving, preparation of lacquer peels of cores, heavy-liquid separation of mineral sands, and XRF determinations of Zr, Ti and Fe.

Preliminary results

Pre-existing seismic reflection data over the inner shelf in the areas covered by the Sonne surveys consisted of regional lines collected by BMR in 1970 and 1972, more detailed work in New South Wales water by BMR in 1974, and very detailed work in Newcastle Bight by the Geological Survey of New South Wales, also in 1974. The Sonne airgun profiles, which were spaced about 4 km apart, provided much additional insight into the thickness and structure of the superficial sediments, although both penetration and resolution commonly left much to be desired. Over much of the area three sequences separated by unconformities can be recognised in the Cainozoic section overlying acoustic basemen+. Maximum thicknesses of the sedimentary section are represented by two-way travel times in excess of 200 ms in the areas surveyed. Both the

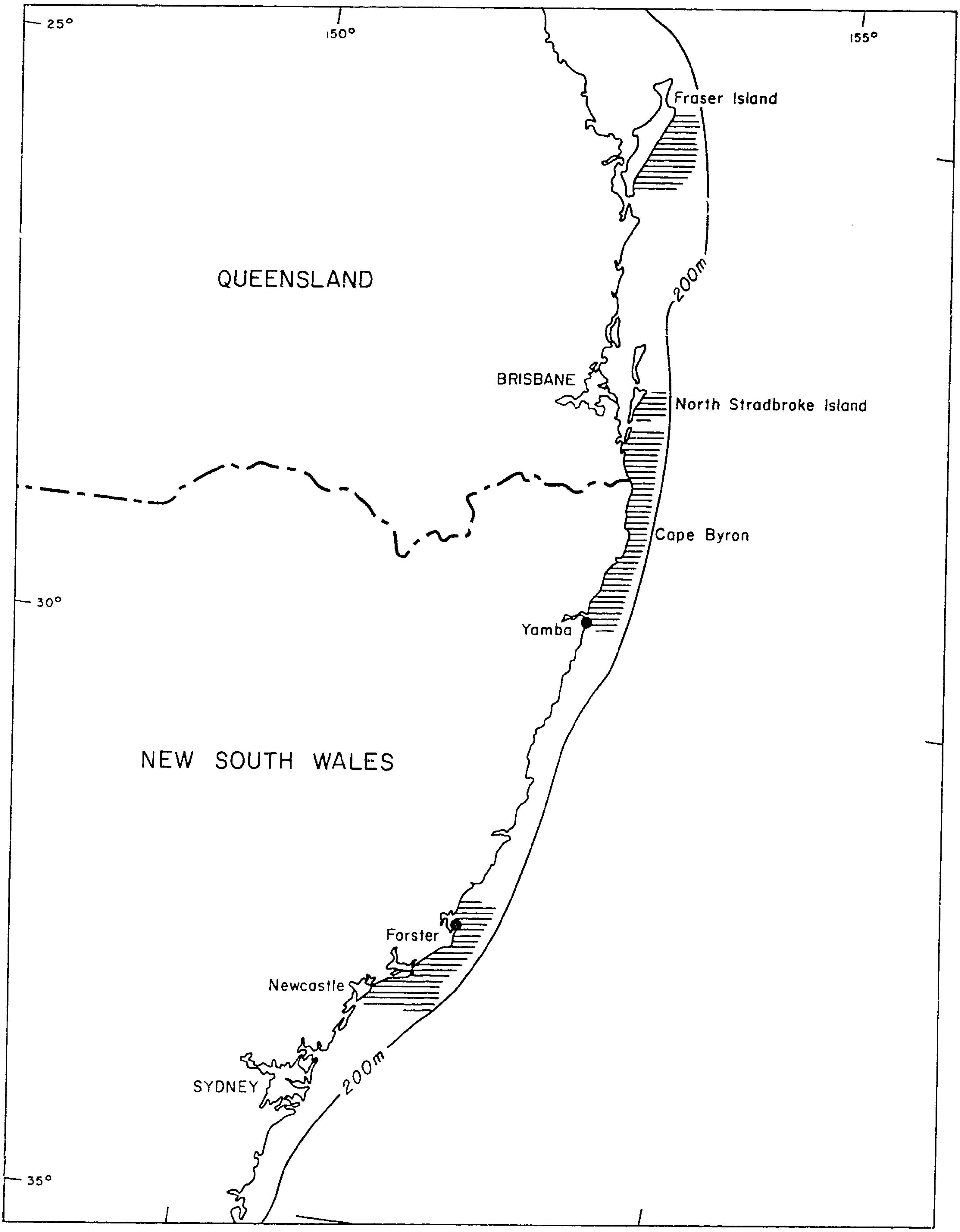

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Fig S3 Location of areas surveyed during Cruise SO-15, September-November 1980 uppermost sequence (Sequence 1) and the lower sequence (Sequence 3) appear to be largely sandy, and provide evidence of conglomeratic fill material in channels at their bases. Sequence 2 is characterised by strong subparallel reflectors and may consist of interbedded sandy and clayey units. Both Sequence 3 and Sequence 2 onlap basement westwards.

Some sub-basement penetration was achieved in the Newcastle-Port Stephens area, allowing the northern boundary of the offshore Sydney Basin to be defined at a number of places.

Nearly all the surface samples and most of the core material consist of marine sediments deposited or reworked since the Holocene transgression. Lower Holocene and Pleistocene paralic and shallow-marine sediments, commonly strongly leached and oxidised by subaerial weathering, were penetrated in many of the coreholes also.

The marine upper Holocene sediments consist mainly of fine and medium-grained shelly sands, brownish in colour and cleanwashed close inshore, and tending to olive grey and slightly muddy in deeper water. Substantial thicknesses of nearshore sand (20 m or more) have accumulated in the region of prominent headlands such as Cape Byron and Cape Hawke. Coarse brown calcareous sands and gravels are widespread on the middle and outer shelf in water depths of over 50 m. These consist mainly of reworked shallow-water shells mixed with modern benthos and little or no modern terrigenous material.

The lower Holocene and upper Pleistocene sediments represent a wide range of shallow-marine, estuarine, lagoonal, and subaerial environments. They include dune sands leached of most of their original shell component, stiff black estuarine and lagoonal clays, peats, and beach deposits. Carbonate-cemented horizons are common. A thin conglomerate sometimes occurs at the top of the sequence, but commonly the overlying shallow-marine sands of the Holocene transgression rest directly on lower Holocene or Pleistocene estuarine or back barrier deposits.

The heavy-mineral content of the offshore sediments is almost everywhere low, and furthermore the proportion of rutile and zircon in the heavy fraction is usually much less than it is in the onshore deposits. Some enrichment with heavy minerals was recorded in individual samples from the near-surface layers of the thick bodies of nearshore sand adjacent to headlands such as Cape Byron, where the fine sand fraction of the sediment (32-315 microns) in water depths of about 20 m contain up to 6 per cent heavy minerals, about half of which consists of rutile plus zircon. The average heavy-mineral content of all near-surface samples in the immediate vicinity of the scattered high-value occurrences is, however, very low.

GREAT BARRIER REEF STUDIES

by

J.F. Marshall

STAFF: P.J. Davies, J.F. Marshall, B.M. Radke, J.B. Colwell, K.A. Heighway, B.G. West, H. Hughes, T. Dalziell, L.S. D'Arcy, D. Foulstone.

The broad aims of this project are to identify and describe the factors controlling the growth and maintenance of coral reefs, and to study the evolution of reefal structures during the late Cainozoic and the stratigraphy of their associated sediments.

Central and Northern Great Barrier Reef

Fieldwork continued in the central Great Barrier Reef region (18° - 19°30'S) during March-May with detailed studies being carried out on three reefs (Myrmidon, Bowl, and Pith). Field activities included shallow drilling, surficial facies mapping, sediment sampling, and water monitoring. This work is a continuation of the previous year's survey when three other reefs in the area (Wheeler, Viper, and Stanley) were investigated using similar techniques. Preliminary results indicate that the outer reefs in this region have substantially thicker Holocene reef sequences than do the reefs farther inshore and the reefs of the southern Great Barrier Reef. At Myrmidon Reef three holes were drilled to depths of between 21.5 and 28.6 m. The reef framework in all three holes consisted of branching corals whose intervening cavities had been extensively infilled by lithified internal sediments. At Bowl Reef three holes were drilled to depths of between 27 and 30 m without reaching the Holocene/Pleistocene boundary. In contrast to Myrmidon Reef the framework at Bowl Reef was extremely open, comprising numerous cavities that were either empty or partly filled with unconsolidated sands.

Water and sediment monitoring on Myrmidon and Bowl Reefs indicated variable movement and low sedimentation during relatively calm conditions. However, during periods of increased southeasterly wind conditions (10-20 knots), Bowl Reef experienced unidirectional water movement across the reef surface from windward to leeward with water velocities in excess of 100 cm. sec^{-1}. A limited program of measuring water movement within boreholes indicated slow but steady movement through the reef in the direction of surface water movement. Drafting of the first composite map of Wheeler, Viper, and Stanley Reefs at 1:10 000 is near completion.

In September/October the field operations were shifted to the reefs off Cooktown. Two reefs (Ribbon No. 5 and East Hope) were investigated. Four holes were drilled on Ribbon No. 5: three on the windward margin and one on a leeward patch reef. Three holes were drilled at East Hope Reef: two on the windward margin and one on a leeward patch reef. Monitoring at both reefs showed the contrast in energy affecting the exposed Ribbon No. 5 and the protected inner shelf East Hope Reef.

Southern Great Barrier Reef

Cores from One Tree, Wreck, Fitzroy, and Fairfax Reefs have been petrographically analysed and radiocarbon analyses assessed. At One Tree Reef, five facies have been delineated from the reef cores; two of these facies - coral heads and branching corals - are dominant on the windward and leeward margins respectively. The development of a particular facies appears to be directly related to the energy; thus the more resistant coralline-algal-encrusted coral heads predominate on the high-energy windward margin, whereas an open framework of branching corals predominates on the more protected leeward margin. Vertical facies variations reflect environmental changes within certain environments.

Vertical accretion rates during the Holocene at One Tree Reef have varied between 0.6 and 8.3 mm. yr^{-1}.

While these accumulation rates appear to be linear, in almost every hole a change in rate was encountered, either an increase or a decrease, that could not be related to obvious changes in the framework.

PHOSPHORITES ON THE EAST AUSTRALIAN CONTINENTAL SHELF

by

J.F. Marshall

STAFF: J.F. Marshall, P.J. Cook (ANU)

Phosphatic-glauconitic-goethitic nodules occur on the continental shelf of eastern Australia (29-32°S) in water depths of 200-300 m. While the nodules are petrologically complex, late-stage carbonate-fluorapatite crystallites within them bear a striking morphological resemblance to relatively young phosphorites from Chile and Peru.

Geochemically the nodules are high in Fe and relatively low in Ca and P in their bulk composition, but microprobe analyses indicate collophane-rich material (av. 29% P_2O_5) in parts of the matrix. However, much of the matrix has been contaminated by iron (up to 61% FeO) and glauconite pellets.

This type of phosphorite occurs in a region of only limited seasonal oceanic upwelling, which therefore differs from many of the classical phosphorite provinces of the world.

BMR EARTH SCIENCE ATLAS

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

Atlas sheets showing (1) sedimentary sequences and (2) petroleum and oil shale were printed. Their explanatory commentaries are with the editors. The coal map and commentary are with the editors.

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

The coal map shows coal measure sequences according to age and depth together with basic structural information and an indication of areas affected by igneous intrusions. The economic importance of the established coal fields is illustrated by histrograms showing coal production and reserves.

The petroleum and oil shale sheet shows the locations of oil and gasfields and oil shale occurrences. The stratigraphic distribution of oil, gas, and oil shale is depicted, together with petroleum reserves.

COAL STUDIES

PERMIAN COALS OF EASTERN AUSTRALIA

by

H.J. Harrington

BMR STAFF: H.J. Harrington, A.T. Brakel, A.R. Jensen (part-time), S. Radke (from April), J. Totterdell (from April), A.T. Wells (part-time from September), P.E. O'Brien (part-time from August).

CSIRO STAFF: M. Middleton (resigned 5.10.81), J.Hunt, G.H. Taylor (part-time), M. Ziekenheiner (resigned 31.7.81), M. Shibaoka (part-time)).

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 is intended to provide an understanding of the relationship between a) the nature and quality of coal and the factors affecting its economic recovery 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 base 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 is the construction of a series of maps, as detailed as possible, covering the palaeogeography and sedimentology of the Permian Period in eastern Australia. Other maps show information on coal type and properties at the time of deposition. Each palaeogeographic reconstruction will be regarded as a starting point in considering the subsequent geological history, including burial, igneous intrusion, tectonic disturbance, and stripping of overburden by erosion.

All staff having been appointed and taken up duty, the project started on 1 March 1980. Work on coal properties such as rank, coal type, and sulphur content is being done mainly by the CSIRO team; the structural, stratigraphic, and tectonic studies are being carried mainly by the BMR team; and both teams are involved inthe overall synthesis.

The whole project, including the writing up of the report, is to be done within the period of the grant, which is 600 working days. Efforts have been concentrated on the Sydney, Gunnedah, and Bowen Basins because of their economic importance, but some work has been done on the Galilee Basin and on the Permian coal measures beneath the Murray Basin.

The work has to be aimed at a broad synthesis. The compilation scale is 1 to 1 million, and data are being assembled at "control points", which have to be about 25 km apart because only a few hundred of them can be incorporated in 600 working days. Quite by chance the BMR and CSIRO teams have used different control points. This is because BMR workers use mainly deep drillholes for stratigraphic information, but where those holes intersected coal it was seldom that the coal was cored, preserved, or analysed. Consequently the CSIRO team has had to use shorter exploration holes in which the coal was cored, and preserved in State core libraries.

Where possible the BMR team uses data from drillholes for which there are well-completion reports on open-file in BMR archives or open-file reports in the Department of Mineral Resources in New South Wales or in the Department of Mines in Queensland. A considerable amount of work is involved in selecting control points. Moreover, well-completion reports are usually massive volumes, and it takes time to extract data from them and to reconcile conflicting interpretations of the logs and the different correlations between wells. Different workers can differ by hundreds of metres vertically in the points that are correlated in neighbouring wells, because of different philosophies about stratigraphy. Those hundreds of metres of difference can have dramatic effects on structure-contour and isopach maps and on palaeogeographic reconstructions. In parts of the Bowen Basin, and in the Hunter and Goulburn valleys, it has been necessary to do field checks to resolve some of the problems.

There were and are difficulties in setting up an ADP format for the data that are extracted from the well-completion reports and other sources, but some structure and isopach maps have been successfully machine-drawn.

A major effort has been made by the team to get improved stratigraphic correlations inside the Sydney and Bowen basins and also between them. One of the theories that is being tested while doing the stratigraphic work is that of Vail, Mitchum, and other EXXON geologists concerning frequent global eustatic changes in sea level of hundreds of metres. Using their general approach, Brakel has developed a correlation model for the Sydney and Bowen basins; comparisons of the model with the palynology and palaeontology suggest that, in the Late Permian, climatic zones moved southward with time. Palaeontological help has been given by Dr J.M. Dickins. This work has been complemented by the work of Hunt in the CSIRO team. He is doing microlithotype studies of the coal seams, and has been able to show that seams that are equivalent to the distinctive Bayswater Coal of the upper Hunter Valley extend from the Gunnedah Basin (Hoskissons Seam) to the southern Sydney Basin (Woonona Coal Member). In most districts this widespread coal occurs just above a marine intercalation in the coal measures. Middleton (CSIRO) and Harrington (BMR) have been interested in rank changes, particularly in the coal seams of the Dawson Folded Zone in the Bowen Basin, and the relations between those changes on the tectonic history of the basin. Middleton presented a paper on the topic at the Geological Society Convention in Perth in August. Harrinton and Brakel gave a paper on the formation of the Sydney Basin and the Gunnedah Basin at a specialist meeting on the Western Coalfield. Brakel gave a lecture on the Sydney, Gunnedah, and Bowen basins in February to a large delegation from the New Energy Development Organisation of Japan (NEDO). The basement lithologies below the Sydney Basin in the Hunter Valley region were discussed in another paper by Brakel at the 15th Newcastle Symposium on Advances in the Study of the Sydney Basin. At the same meeting Middleton and Hunt gave papers on their work on coal type and coal rank. Before he resigned Middleton prepared a report on the results of his work on the project to be published in the CSIRO series of Investigation Reports.

The project is about half completed and is to end when the NERDDC grant ends in February 1983.

SUMMARY REPORT ON COAL IN AUSTRALIA

by

A.T. Wells

The report, to be issued as a Record, presents the results of a brief review of the occurrence of coal in the onshore sedimentary basins of Australia.

The aim was primarily to assess the current status of geological information and where possible to identify deficiencies in knowledge.

The report includes all known deposits regardless of whether they are major economic deposits or minor occurrences, subeconomic, deep, or worked out.

The data are organised under a standard set of headings arranged in the same order for individual deposits so that the relevant information can be found quickly, and a comparison and rapid assessment of the information can be made. Wherever possible generalised notes have been compiled on both geological and mining problems remaining to be resolved.

The information has been extracted mainly from monographs which give major reviews of coal deposits, and data on recently discovered deposits or known areas have been added where significant new information has been obtained.

The principal sources of information are listed for each deposit, and tables and plates are included to show coal measure correlations for each period, location of major coal occurrences in Australia, and operating and proposed mining areas in the Sydney and Bowen Basins.

Many of the problems associated with the exploration and exploitation of coal measures can be solved by a thorough understanding of the controls exerted by structure and depositional environments on the distribution and quality of coal in coal measure sequences.

Many of the potential hazards pertaining to the exploitation of the coal can be directly related to different inter-seam rock types, igneous intrusions, and structure. Prediction of the problems to be encountered ahead of mining is an important aspect of geological investigations.

In many basins it is apparent that the influence of these geological constraints has not been assessed owing to the lack of detailed information on the sedimentary sequences, and conflicting correlations and confusing nomenclature within sedimentary basins.

A great deal of fundamental geology remains to be resolved in the study of coal-bearing sedimentary basins.

OIL SHALE STUDIES

OIL SHALE METHODOLOGY PROJECT: TOOLEBUC FORMATION INVESTIGATIONS

by

H.F. Doutch

STAFF: BMR Project Leader H.F. Doutch; Principal Investigator S. Ozimic; D.L. Gibson (part-time)

This is a partly NERDDP-funded joint project with the Mineral Research Laboratories of CSIRO. Work in BMR on the project began at the end of February 1980, and is scheduled to be completed by the end of February 1983.

The aim of the project is to develop methods to assist government and industry to assess the potential of a widespread sedimentary sequence as a possible future source of shale oil. The project is initially based on a study of the Toolebuc Formation of the Eromanga Basin of South Australia, New South Wales, and Queensland. Samples from project and past drilling will be examined for lithology and organic content both microscopically and chemically, and these results correlated with geophysical logs of the drill holes. Stemming from this work the geological controls for the accumulation of the oil shale will be deduced, and the significance of this information in assessing oil shale resource potential evaluated.

During 1981, BMR and CSIRO began processing samples from cores taken during the previous year's drilling. Laboratory results are not available at the time of writing. Dr Ozimic prepared a report on the drilling available as BMR Record 1981/12. More generally, the gross response of the Toolebuc Formation to wire-line logging is clear-cut, and is most obvious on gamma-ray and density logs. Correlation of logs with oil shale grade awaits analytical results. Where oil shale has been proven, it is associated with a gamma-ray anomaly, but the reverse proposition does not hold everywhere. Fluid that flowed to the surface from the Toolebuc Formation from eight holes during drilling is a mature hydrocarbon probably of terrigenous origin, which could not have been derived from the normal marine type kerogen of the unit.

Five holes were drilled in the Charleville area of Queensland with a BMR rig and logged by BMR. Oil shale was found in only one of them, but a Toolebuc Formation equivalent may be present in some or all of the others. A drilling report Record is in press, and samples from cores await analysis.

Two further drilling programs were arranged, one between Charleville and the New South Wales border, and the other in the Boulia area of Queensland.

Both should be completed by the end of 1981. Company reports and cores from the Boulia area were studied in preparation for the drilling and as part of the project's data gathering function.

Dr Ozimic was on leave from the project for 12 weeks on an overseas tour as part of a Churchill Fellowship awarded to further his studies on the underground storage of gas. Mr. D. Gibson supervised some of the drilling during his absence.

AUSTRALIA-WIDE OIL SHALE STUDIES

by

D.L. Gibson

The object of these studies is to assess Australia's oil shale resources; keep an up-to-date bibliography of oil shale and shale oil in Australia; enquire into the origin and geology of Australia's oil shales; and provide geological advice to industry.

These functions were carried out during 1981, and two major review papers on Australian oil shale were prepared for publication. Assessments of shale oil resources were made on a quarterly basis, and passed to Petroleum Exploration Branch for computerisation and circulation.

PALAEONTOLOGICAL STUDIES (Fig. S4)

EARLY PALAEOZOIC FAUNAS

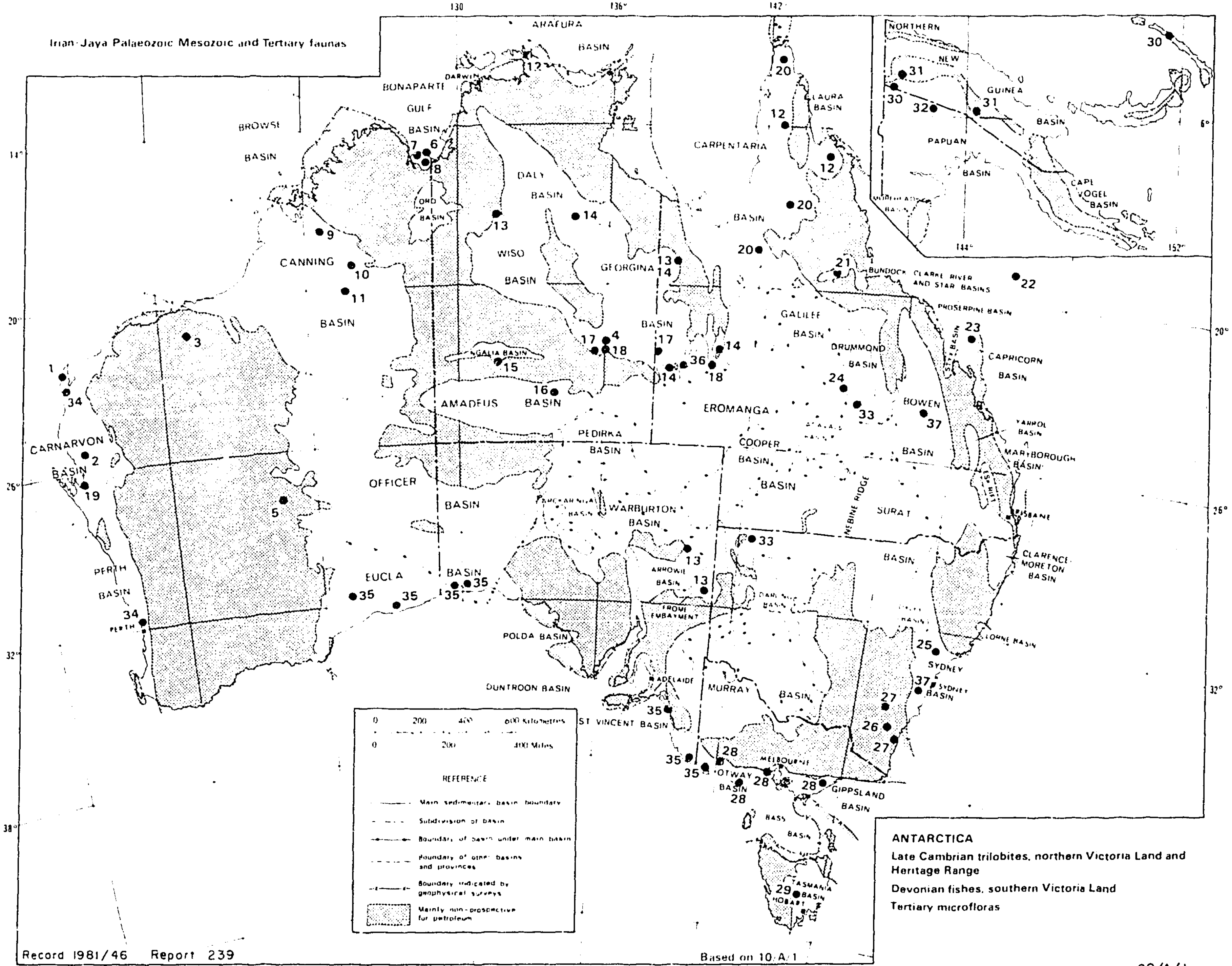
CAMBRIAN-ORDOVICIAN TRILOBITES (J.H. Shergold)

J.H. Shergold returned to BMR at the beginning of February 1981 having spent twelve months as an Alexander von Humboldt Research Fellow at the University of Wurzburg, West Germany. Normal duties, as co-ordinator of the Georgina Basin Project, were resumed at that time.

During the tenure of the Alexander von Humboldt Fellowship, Late Cambrian and Early Ordovician trilobites from northern Spain and central Turkey were investigated. The preparation of this work for publication continues. Similarly, work on Late Cambrian trilobites from Antarctica is continuing. Material collected by the NZ Antarctic Expedition in 1973 to north Victoria Land and the 1979 U.S. Expedition to the Ellsworth Mountains, at the other end of the Transantarctic Mountains, has been prepared and photographed, but awaits systematic description. Systematic descriptions of the Early Ordovician trilobite faunas of the Georgina Basin, in collaboration with R.A. Fortey

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

OTHER AREAS
Late Cambrian trilobites NE Spain and central Turkey



ANTARCTICA
Late Cambrian trilobites, northern Victoria Land and Heritage Range
Devonian fishes, southern Victoria Land
Tertiary microfloras

20/A/1

Fig. S4 Current palaeontological projects

(British Museum), are well advanced. These research projects will lead to a better understanding of circum-Gondwanaland biofacies during the Late Cambrian and Early Ordovician, and place northern Australia more accurately in a regional geological context.

International activities, as co-Project Leader of IGCP Project 156 (Phosphorites); as co-ordinator of the Cambrian Correlations Working Group of the Commission on Stratigraphy, Subcommission on Cambrian Stratigraphy; and as Vice-Chairman of the COS Cambrian-Ordovician Boundary Working Group, were also continued. Activities on behalf of the COS Cambrian Subcommission were catalysed by attendance at the 2nd International Symposium on the Cambrian System, held at the Colorado School of Mines in August 1981, at which a review of the possibility of a global zonation of Late Cambrian time based on agnostid arthropods was presented. At this meeting a technical session on Cambrian biostratigraphy and intercontinental correlations was chaired; a meeting to consider progress in the production of correlation charts for the Cambrian of the world was convened; and the business meetings of the Cambrian Subcommission were attended. Following the Cambrian Symposium, field excursions to Oklahoma, Texas, and Newfoundland, which emphasised sequences around the Cambrian-Ordovician Boundary, were attended. It is now possible to correlate the cratonic North American sequences, through allochthonous/autochthonous trilobite/graptolite sequences in Newfoundland, with the basal Tremodocian Dictyonema flabelliforme flabelliforme Zone, with a high degree of resolution. With the aid of trilobites and conodonts it is possible to establish this level in North American cratonic sequences at the base of the Hirsutodontus simplex conodont Assemblage-Zone in Oklahoma and Texas. This species, originally described from the Georgina Basin, therefore permits correlation between northern Australia and the type Tremadoc area of North Wales.

CAMBRIAN OSTRACODS (P. J. Jones)

A short nomenclatural note on 'Flemingopsis, a new name for the Cambrian phosphatocopine ostracode genus Flemingia Jones & Mackenzie, 1980' was published in Alcheringa.

ORDOVICIAN CHITINOZOANS (M. Owen)

Chitinozoa are an extinct group of acid-insoluble, flask-shaped microfossils less than 0.5 mm long which range from the earliest Ordovician to latest Devonian. Their biological affinities are uncertain, but they may represent the egg capsules of an extinct metazoan. They have proved to be of considerable value for correlation in North America, Europe, and north Africa, being short-ranging, cosmopolitan in distribution, and often very common in sedimentary rocks. These attributes are of particular value in oil exploration since only small samples such as can be obtained from drill core may be processed using standard palynological techniques for chitinozoa.

This new study is investigating their usefulness for correlation within Australian sedimentary basins, and with areas outside Australia. The initial stage of the investigation has looked at the distribution and preservation of chitinozoa from various areas of Australia. So far, well-preserved chitinozoans have been separated from samples from the Ordovician of the Canning and Amadeus Basins and rather poorly preserved specimens from the Silurian of the more deformed Lachlan Fold Belt. The limited work done so far has demonstrated that they will be potentially useful and more detailed work will be done in the coming year to develop a biostratigraphic zonation for use in Australia.

SILURIAN AND EARLY DEVONIAN FAUNAS (D.L. Strusz)

Strusz is engaged in a biostratigraphic and systematic study of the Silurian to Early Devonian faunas of southeastern Australia, particularly those in the Canberra region. This study is aimed at:

1) extending the presently very limited knowledge of those faunas,
2) improving correlation within, and understanding of, the geological history of the Lachlan Fold Belt, and
3) contributing to IGCP Project Ecostratigraphy.

Work is now concentrated on Silurian brachiopods - on which little has been done for fifty years or more. Completed studies include the description of a Wenlockian fauna from the Molonglo valley near Coppins Crossing, west of Canberra; a discussion of the relationships of a group of lissatrypid genera (of which there is a species at Coppins Crossing); and the description of a new Silurian species of the strophomenacean Maoristrophia (hitherto described only from Lower Devonian rocks, and involved in controversy over the age of appearance of the Baragwanathia flora in Victoria). Preparation of material has started for the description of the fauna of the Yarralumla Formation, of probable early Ludlovian age.

A short note was prepared, with Dr C.J. Jenkins (ANU), discussing the implications for Canberra stratigraphy of a Monograptus exiguus from rocks below the unconformity now exposed in the State Circle road cut beside Camp Hill.

LATE PALAEOZOIC FAUNAS AND FLORAS

DEVONIAN FISH (G.C.Young)

Research objectives in the study of Palaeozoic vertebrate faunas are to provide a systematic basis for dating and correlation of non-marine and marine Palaeozoic sediments, and for biostratigraphic and biogeographic analysis relevant to the solution of geological problems. During the year, work on localities in the Lachlan Fold Belt continued with the publication of descriptions of new taxa from the Early Devonian marine fauna from Taemas/Wee Jasper, and the freshwater fauna from the overlying Hatchery Creek Conglomerate (Middle Devonian), and the completion and submission of a manuscript on Middle/Late Devonian freshwater shark remains from the NSW south coast, and South Victoria Land, Antarctica. Identification of the same species from the last two localities provides evidence for correlation between the lower sediments in the Boyd Volcanic Complex (the Bunga beds) of southeast NSW, and the lower part of the Aztec Siltstone, Beacon Supergroup, in Antarctica. Another paper was published on world biogeography of Devonian vertebrates, and further preparation and study was undertaken on species of the placoderm Bothriolepis, from Antarctica and southeastern Australia, as a basis for more detailed correlation between these areas.

Fieldwork was restricted to short collecting trips to the Burrinjuck Dam area, and to a new Frasnian locality near Braidwood. For the Amadeus and Georgina Basin projects, some preliminary description and faunal analysis was carried out, and photographing of the 1974 and preparation of the 1977 Georgina Basin collections from the Cravens Peak beds were continued as time permitted. Preliminary work indicates a new species of Wuttagoonaspis, and several other placoderm species and genera not known from the Wuttagoonaspis fauna in the Mulga Downs Group of the Cobar Basin. However, the Mulga Downs and Cravens Peak faunas are still regarded as broadly contemporaneous.

Preparation and study of the Gogo collection from the Canning Basin was continued, and a representative collection of prepared specimens and display material was sent to the Geological Survey of Western Australia. Other preparation using acetic acid techniques was carried out on material from Taemas/Wee Jasper, Toko Syncline (Georgina Basin), and Broken River Formation (Queensland).

Curation of collections involved 113 vertebrate specimens being added to the fossil registers, and 42 to the Commonwealth Palaeontological Collection. Various enquiries from the public were answered or investigated, two manuscripts were refereed, and one book was reviewed for outside journals.

DEVONIAN AND CARBONIFEROUS OSTRACODS (P.J. Jones)

The study of Devonian and Early Carboniferous ostracod faunas from various regions in Australia was continued. Research objectives are to elucidate the biochronology of these faunas, and to interpret their evolutionary, environmental, and biogeographic significance. Current work on Western Australian faunas, in collaboration with R.S. Nicoll (conodonts), is concentrated on those within the onshore Bonaparte Gulf Basin.

Bonaparte Gulf Basin: Taxonomic revision of a manuscript on Early Carboniferous ostracods continued, and a preliminary investigation of their distribution in surface samples from the Burt Range Formation (BMR 1972 collection) indicates that some refinement of the biostratigraphy of the existing ostracod scale is necessary. Examination of subsurface samples (Aquitaine Australia Minerals collections), combined with results from previous ostracod and conodont studies, provide a biostratigraphic framework which has been used to interpret the palaeoenvironmental significance of the lithofacies. This interpretation was presented at the Fifth Australian Geological Convention, Perth (BMR Professional Opinion 1981/014). Samples were collected (with R.S. Nicoll) in an attempt to solve specific stratigraphic problems in the Jeremiah Hills, Milligans Hills, Spirit Hill, and Ningbing Range. These problems were discussed with AAM and GSWA geologists in the field.

Georgina Basin: A paper describing an Early Devonian microfauna, consisting of thelodont scales, abundant eridostracans, and some ostracods was published (jointly with S. Turner, Queensland Museum, and J.J. Draper, Geological Survey of Queensland), based on material from the Cravens Peak beds of the Toko Syncline, western Queensland. The combined evidence of this fauna suggests a late Early Devonian (Emsian) age for the Cravens Peak beds.

Cobar Basin: A short note on a marine fauna from core samples taken from BMR Ivanhoe No. 1 well was prepared jointly with D.L. Strusz and R.S. Nicoll (BMR Professional Opinion 1981/002). The fauna, consisting of ostracods, bracniopods, tentaculitids, and conodonts, is Early Devonian (Lochkovian-early Pragian), and is similar to that of the outcropping Amphitheatre Group.

DEVONIAN AND CARBONIFEROUS CONODONTS (R.S. Nicoll)

Robert S. Nicoll continued with the study of conodont faunas from Australia and adjacent areas. In co-operation with Dr John Pickett (NSW Geological Survey) Lower Silurian sections have been sampled in the vicinity of Orange, NSW. It is their intention to establish biozones in biostratigraphic reference sections in the Orange-Molong region which can be extended into areas with less well-exposed or developed Silurian sequences throughout eastern Australia.

The study of Devonian and Carboniferous conodont faunas from Western Australia and the Northern Territory continues as a joint project with Dr P.J. Jones (BMR, ostracods). Conodont faunas from the Bonaparte Gulf, Canning, and Carnarvon Basins have been collected and are now being studied. Most active work is currently directed toward the Bonaparte Gulf Basin, where conodont faunas collected by BMR in 1972, 1980, and 1981 are being studied in combination with subsurface samples provided by Elf Aquitaine Australia.

Preliminary revision of the Early Carboniferous conodont and ostracod biozonation (Professional Opinion 1981/014) was presented at the Geological Society of Australia meeting in Perth (August 1981).

A limited number of samples from Irian Jaya have been examined and conodonts indicating a Late Carboniferous (two samples) and Siluro-Devonian (two samples) age for the sediments have been identified.

A small Early Devonian conodont fauna was identified from BMR Ivanhoe No. 1 Bore from western NSW on material provided by V. Passmore (BMR Petroleum Exploration Branch).

PERMIAN BIOSTRATIGRAPHY (J.M. Dickins)

A publication with Dr K.H.R. Moelle, Department of Geology, University of Newcastle, "The geology of the border region of the Sydney Basin and the New England Fold Belt" is being prepared. As a part of this an historical review of work on the structural development and sedimentation has been undertaken. This review shows a reversal on the 'Hunter lineament'. In the Late Carboniferous, material was shed from the present site of the Sydney Basin into a trough northeast of the lineament. In the Permian, material was being shed from the northeast, southwestward into the Sydney Basin.

Work on the time framework of sedimentation has been undertaken for the NERDDP Permian Coal Project. A number of bore logs in the Bowen Basin have been examined with A. Brakel in order to supply more precise information on the lateral and vertical relationships of coal-bearing units. Fieldwork was undertaken with A. Brakel on the upper part of the predominantly marine sequence (Back Creek Group) and the upper coal measures (Blackwater Group). These intervals contain coal which is being mined intensively. The work has shown that the distribution of coal in the upper part of the Back Creek Group

(Moranbah and German Creek Coal Measures) is influenced by the distribution of a complex quartz sand and conglomerate body coming from the west. Further work on the correlation of the Upper Permian sequences in the Bowen and Sydney Basins is planned.

A manuscript (jointly with S.K. Skwarko) "Upper Palaeozoic pelecypods and gastropods from Irian Jaya, Indonesia" has been completed and is awaiting publication by the Geological Research and Development Centre (GRDC), Indonesia. The fauna has affinities with that of the Permian faunas of Western Australia.

Another manuscript entitled "Posidoniella, Atonodesma, the origin of the Eurydesmidae and the development of the pelecypod ligament" is nearing completion. This arises from the joint project being carried out with the British Museum (Natural History) London.

PERMIAN PALYNOLOGY (E.M. Truswell)

Minor photographic work was carried out on Joe-Joe Group microfloras during 1981. Additionally, siltstones immediately overlying glacial deposits at Lerderderg Gorge in Victoria were examined, and yielded rich, well-preserved microfloral assemblages. These have been assigned to late Stage 2 of the eastern Australian palynostratigraphic scheme (BMR Professional Opinion 81/009).

MESOZOIC FAUNAS AND FLORAS

MACROFOSSILS (S.K. Skwarko)

Systematics and biostratigraphy

S.K. Skwarko's identification of Cretaceous ammonites from Papua New Guinea brought to light genera new to the area and species new to science. In addition some Australian species of Aptian age were identified, enabling direct correlation between the two countries.

His work on the Upper Cretaceous molluscs from Mountnorris Bay, northern Arnhem Land, NT, enabled correlation of the local Cenomanian strata with those of Bathurst Island 300 km to the west.

Skwarko also described two new Trigoniidae from the Triassic strata of the western United States.

Results of all the above investigations are being prepared for publication. Six papers published during the year were distributed.

Macropaleontology Research Group and Laboratory, GRDC, Bandung, Indonesia

Skwarko spent two months in the Bandung Laboratory, training local staff and assisting in the day-to-day running of the laboratory.

In Canberra he completed and submitted to the GRDC for publication three MSs dealing with Irian Jaya (including the Misool Archipelago) strata and fauna; edited a further four MSs for publication by the GRDC, and generally co-ordinated paleontological effort connected with the geological mapping of Irian Jaya.

CRETACEOUS PALYNOLOGY (D. Burger)

Carpentaria Basin

A manuscript entitled "A basal Cretaceous dinoflagellate suite from northeastern Australia" was completed; it discusses a palynological investigation of the Gilbert River Formation, Helby beds, and the lower part of the Rolling Downs Group. This investigation is part of a larger palynological study of the Cretaceous in the basin and evaluates the earliest Cretaceous history of the basin up to the time of the great Aptian marine transgression in Queensland. This paper is to be published in Palynology 5 (in press).

Conferences

The abstract of a paper entitled "Albian angiosperm distribution and habitat in Queensland, Australia" was submitted to the Fifth International Palynological Conference (Cambridge, 1980). The manuscript of the first part of this paper, dealing with early-middle Albian angiosperms of the Surat Basin, is now ready. The second part, which covers the late Albian angiosperms of the Eromanga Basin, is now being revised on the basis of new biostratigraphic and taxonomic data which became available through the NERDDC program (see below). Burger also attended the 13th International Botanical Congress in Sydney (21-26 August).

BMR/CSIRO NERDDC Oil Shale Methodology Project

Palynological work in connection with the NERDDC Project, which involves the Toolebuc Formation in the Eromanga Basin, was started and so far has incorporated samples from three boreholes: BMR Urisino No. 1, BMR Augathella No. 6, and BMR Jericho No. 11 (BMR Record 81/82).

BMR Urisino No. 1 was drilled in northwestern New South Wales, and palynological examination demonstrated that strata equivalent to the Toolebuc Formation (or Wooldridge Limestone Member, Oodnadatta Formation) are present in the Bulloo Embayment, southern Eromanga Basin (Professional Opinion 80/016).

BMR Jericho No. 11 and BMR Augathella No. 6 are part of a drilling program in the eastern Eromanga Basin (Queensland) which is continuing. Palynological work to date (a) has confirmed earlier data from the southern Carpentaria Basin (still unpublished) that the Toolebuc Formation is associated with the late Albian Phimopollenites pannosus zone, and (b) has indicated the marginally marine character of the formation at the drill-sites.

CRETACEOUS FORAMINIFERA (D.J. Belford)

D.J. Belford completed a manuscript revising the generic position of costellate planktic foraminifera from the Late Cretaceous of Western Australia. These forms, originally referred to the genus Rugoglobigerina, are now placed in Whitenella. This change removes a Santonian record for Rugoglobigerina, which may prove to be an index for beds of Campanian age.

A probable Coniacian fauna from an excavation on the Giralia Anticline, south of CY Creek, has been described. This is the oldest fauna yet know from carbonate beds in this area and indicates that carbonate sedimentation began earlier than had been thought previously.

The study of a Cenomanian planktic fauna from Papua New Guinea began. This fauna contains a species of Planomalina with a distinct double keel rather than the single thickened keel known previously, and the diagnosis of the genus may require modification.

Late Cretaceous faunas were recognised in material forwarded by the Irian Jaya Geological Mapping Project, but no detailed work has been done.

CAINOZOIC FAUNAS AND FLORAS

FORAMINIFERA (D.J. Belford & G.C. Chaproniere)

D.J. Belford has revised the manuscript describing Tertiary foraminifera from the Ok Tedi and Wabag 1:250 000 Sheet areas, Papua New Guinea, to take into account recent literature and comments by colleagues. The plates, sample locality maps, tables and text-figures are completed and the manuscript is ready for final typing.

Samples submitted by the Irian Jaya Geological Mapping Project were examined and reports prepared. No detailed work has been done on this material. During November, 1980 Belford visited Irian Jaya to examine faunas in the field.

From December 1980 to January 1981, G. Chaproniere took part in the Sonne 16B Cruise in the Coral Sea; various parts of the Queensland Plateau and Coral Sea floor were sampled. At a series of stations at the western edge of the Queensland Plateau near Osprey Reef a large amount of shallow-water limestone was recovered. Subsequent study has shown this to be of latest Oligocene to early Miocene age (lower and upper Tertiary stages). Some of the associations recovered are new to the Australian region, although they have been recorded to the north (in Indonesia). These faunas are similar and of equivalent age to those present in the basal parts of the Wreck Island No. 1 bore, and suggest that the major coral reef growth in the region was initiated at the end of the Oligocene. A sample of middle Eocene limestone was also recovered; this has a distincly warm-water larger foraminiferal fauna (Discocyclina, Operculina, Gypsina, Cymbelloporetta, and a new genus and species), and the sparse planktic fauna indicates a correlation to Zones P.10-11 (early middle Eocene). This fauna indicates that marine shallow-water conditions prevailed at this part of the Queensland Plateau by the early middle Eocene, suggesting that this may be close to the time when submergence of the Queensland Plateau began. Only one other pre-Pliocene planktic fauna was recorded. This (Zone N.3/4) is probably a deep-water equivalent of the reefal material. Quaternary sediments veneer most of the Plateau. On the northeastern margin and in the PNG part of the Coral Sea, gravity cores penetrated only into the Pliocene. Detailed study of the planktic faunas has yet to be made.

Work continued on the study of the relationship between superficial wall texture in mid-Tertiary planktic faunas and environmental factors; no new information can be added to last year's report.

The study of some samples from Irian Jaya and Western Australia led to a revision of the Tertiary e-Tertiary f stage boundary. This was previously equated with the early-middle Miocene boundary (Zone N.8-N.9 boundary), but is now considered to be within the N.6-N.7 zonal interval. These results have now been published.

The systematic part of a study on Australian and New Zealand mid-Tertiary larger foraminiferids has been prepared for publication as a BMR Bulletin. This describes two new taxa and makes a revision of some established taxa using topotypic material. Part of the study used an X-ray technique.

Data have been added to the palaeontological retrieval system and specimens to the palaeontological collections.

<u>NANNOFOSSILS</u> (Samir Shafik)

A procedure was developed to combine the use of optical and scanning electron microscopy in the study of the same nannofossil individual specimens. This is expected to revolutionise our knowledge of many previously described taxa. A manuscript describing the procedure was prepared and sent to the Editor of the Journal of Palaeontology.

The biostratigraphy of Eocene sediments in the Otway Basin was worked out. A scheme of nannofossil events was recognised, complimenting another set of events recognised previously in sediments from the Perth Basin. The Otway Basin events were compared with other events based on foraminiferids occurring in the same sediments, and with other nannofossil and foraminiferal events in the New Zealand late Eocene. A manuscript dealing with these biostratigraphic correlations is being edited (BMR Journal).

Early Tertiary nannofossil assemblages from the Heard and McDonald Islands, southern Indian Ocean were described (Professional Opinion 81/011), and are expected to be published as a part of a paper with Dr P.G. Quilty.

Two manuscripts are in preparation, one describing seven new late Eocene taxa which include three new genera, and another manuscript dealing with Late Cretaceous nannofossils from Western Australia.

Several samples from outside Australia were examined for their nannofossils, upon request from colleagues working on foraminiferids.

<u>PALYNOLOGY</u> (E.M. TRUSWELL)

In 1981 attention was focussed on palynological work in Antarctica, and in the Tertiary of central and southeastern Australia.

In <u>Antarctica</u>, the greatest effort was spent in writing up the results of examination of the recycled palynomorph content of modern muds at a number of offshore localities. The main purpose of this work has been to pinpoint the locations of the source beds of the recycled spores, pollen, and dinoflagellates, and thus to locate sub-ice sedimentary basins. One paper has been completed which deals with the distribution patterns off the east Antarctic coast; sedimentary sequences comprising Permian, Jurassic to Lower Cretaceous, and Upper Cretaceous through Lower Tertiary strata are predicted to exist in the Shackleton Ice Shelf area, in the region offshore from Cape Carr, and in the area to the west of the Mertz Glacier.

Another paper in final stages of preparation deals with the quantitative distribution of recycled material in the Ross Sea. Here, palynomorph distribution patterns clearly show differing source areas for seafloor sediments of the western and eastern Ross Sea. To the west of the Pennell-Iselin Bank, sediments originate from the Transantarctic Mountains, and contain a high relative frequency of Permian and Triassic pollen and spores. To the east of the bank, dense concentrations of palynomorphs reflect a provenance in beds of Late Cretaceous through Early Tertiary age. The coincidence of these regions of high palynomorph concentrations with fast-moving ice streams D and E within the Ross Ice Shelf suggests a source area for the palynomorphs at the head of the shelf, in an area where radio-echo-sounding teachniques have predicted Mesozoic and Tertiary fill within the sub-ice Byrd Basin. The palynological data offers the only real evidence yet available for the age of strata within this basin. In addition to the two described geologically orientated studies, an illustrated, annotated catalogue of recycled forms has been prepared; this will provide a reference for palaeobotanical data, and in effect will serve as a check list for plant taxa that once grew on the Antarctic continent.

A rather general review of vegetation history of Antarctica was prepared and delivered at a conference held in Melbourne in May 1981 entitled 'Antarctica; weather and climate'. This paper is now in press in the Australian Meteorological Magazine, and outlines vegetation history of Antarctica from the Devonian to the Tertiary, stressing in particular the fact that it has been the normal situation for Antarctica to carry a vegetation cover of vascular plants, and emphasising the difficulties of interpreting near-polar plant growth using as a model plant/climate relationships on the modern Earth.

Australian Tertiary palynological studies have progressed during 1981. The main effort has been concentrated on the detailed documentation of the pollen and spore spectra from lignites and siltstones of the Hale River Basin in central Australia with a view to reconstructing plant communites and palaeoclimates for the Eocene in that area. Two major points of interest have arisen with regard to these deposits; first, analysis of algal-rich material produced an oil content in excess of 80 litres per tonne for some samples, and second, of palaeobotanical interest, was the identification of pollen of Duoseraceae in these samples. This record is the oldest in the world for this insectivorous family; previously published records date only from the Miocene. Whether the relationship between this group and nitrogen-deficient soils, which is evident in the modern flora, pertained in the Eocene remains unknown. In addition to work on the central Australian Tertiary deposits, work was also undertaken on an Eocene microflora which underlies basalts at Bungonia in New South Wales. This pollen, spore, and freshwater dinoflagellate assemblage closely resembles those know from lacustrine deposits at Nerriga. The palynology of Tertiary lake deposits drilled by BMR at Bunyan, near Cooma, is currently being investigated by J. Tulip, an honours student in Geology at ANU.

Under the same Tertiary heading, mention should also be made of the highly successful symposium organised in Canberra in November, 1980, on 'Cainozoic evolution of continental southeastern Australia'. This meeting attracted 140 participants from 47 institutions, and topics covered in the two days of lectures and one of workshop sessions included vegetation and climatic history, weathering history, tectonics and economic aspects. The abstracts were compiled into a volume (Bureau of Mineral Resources Record 80/67) by E.M. Truswell & R.S. Abell.

MAMMALS (M. Plane)

The aim of this work is the biostratigraphic correlation of non-marine sediments and the search for possible Mesozoic and Tertiary records of marsupial evolution in Australia and New Guinea.

Work continued on the Bullock Creek fauna from the Northern Territory both in the laboratory and the field, and in the laboratory on elements of the Ngapakaldi and Mamelon Hill faunas from South Australia, and the Riversleigh fauna from Queensland.

In contrast to last year, definitive material has been obtained from the Carl Creek Limestone (Riversleigh fauna), comprising new taxa of diprotodontidae and macropodidae. Fieldwork at Bullock Creek proved outstandingly successful because new sites were discovered and approximately five new taxa of mammals and several new birds were discovered. Preparation is proceeding on two of the new animals - the mandible of a small kangaroo and the exquisitely preserved skull of a small marsupial lion. Both have stratigraphic and evolutionary significance. A very large collection of fossiliferous matrix was made (± 7 tonnes) and the acid preparation of this material will take several years to complete. This work will be done in collaboration with the National Museum of Victoria and Monash University.

Other activities included: preliminary discussions on the proposed integrated study of the Tertiary and Quaternary rocks of the Lake Eyre basin using the disciplines of stratigraphy, magnetostratigraphy, vertebrate palaeontology, and palynology were held with the possible participants from the South Australian Mines Department, Flinders University, American Museum of Natural History, and BMR; the chairing of the fossil mammals section of the special BMR/GSA meetings on the geology of southeastern Australia; attendance at a meeting on fossil bat research (the Riversleigh fauna contains bats closely related to mid-Tertiary European taxa); regular attendance at Palaeontological Technical Services planning meetings; further work on the proposed Palaeontological Store, which will now be built in the coming year; visits to Sydney and Adelaide for discussions with colleagues on joint projects; and the hosting of an informal weekend workshop for fossil mammal and bird workers.

NATIONAL AND INTERNATIONAL COMMITMENTS

J.H. Shergold: IGCP Project 156 (Phosphorites) continues to expand its activities rapidly, and plans to hold its Fourth International Workshop and Seminar at Jaipur, India, in November-December 1981. Associated field excursions will be organised to examine the stromatolitic phosphorites of Udaipur (Rajasthan) and Dehradun (Mussourie). This project now has representation from 25 countries, and over 150 individual scientists have attended its previous meetings.

D.L. Strusz is treasurer and Australian correspondent for 'Fossil Cnidaria', the newsletter of the IPA-affiliated International Research Group on Fossil Corals and Coral Reefs.

J.M. Dickins worked with the Permian and Gondwana Subcommissions of the International Union of Geological Sciences. He is chairman of the Gondwana Subcommission. Brief reports were prepared on China and Tibet and the Carnic Alps and have appeared in the Newsletter of the Permian Subcommission. These contain some comments on stratotypes for the system.

International Botanical Congress: E.M. Truswell has been a member of the committee for the Historical Botany section of this congress since 1977. During 1981 she chaired the section for some months. At the congress, held in Sydney in August 1981, she convened a symposium on the development of plant provinces through geological time. Papers from this symposium are to be published in *Alcheringa* in 1981.

Deep Ocean Drilling: In March 1981 the Consortium for Ocean Geosciences (COGS) convened a meeting in Canberra to put Australia's case for participation in the final phases of IPOD (International Phase of Ocean Drilling). At that meeting E.M. Truswell acted as chairperson of Working Group 3, on Oceanic Palaeoenvironments, presented the recommendations of that Group, and compiled the report for publication (COGS. Publication No. 1, pp.22-27).

CURATION OF NATIONAL COLLECTIONS

D.L. Strusz

1) Further sorting was done of Dr A.A. Öpik's Canberra fossil collection.
2) CPC specimens used by Campbell & Chatterton in their 1980 paper on Canberra trilobites were curated, and prepared for computerised cataloguing.
3) All CPC specimens described by Strusz were prepared for computerised cataloguing.

D.J. Belford. Data on foraminiferal specimens in the Commonwealth Palaeontological Collection were added to the palaeontological data retrieval system. Trial printouts for a catalogue have been done, and a complete catalogue will soon be printed. Information on the general Western Australian foraminiferal collection was also added to the system, and entry of data on Papua New Guinea collections began.

Mrs. E. White. Curation of plant fossils was undertaken under contract. Figured specimens were brought together and information on them was checked and tabulated.

PALAEONTOLOGICAL LABORATORIES

STAFF: A.T. Wilson, H.M. Doyle, R.W. Brown, P.W. Davies, Mrs L. Kraciuk

Seven hundred samples were washed and 200 thin sections prepared for ostracod and foraminifera examination, 1100 samples were picked for ostracods and concostrada; and 160 slides from 80 samples were prepared and examined for nannofossils.

In the Palynology Laboratory 598 slides were prepared from 249 samples processed for pollen and spore examination.

Macropalaeontological work included the acid preparation of 260 fossil fish and vertebrate samples; the processing, washing, sieving, and picking of 2 tonnes of material for mammal remains; the mechanical preparation of 1 tonne of limestone for mammal remains; and the making of 500 rubber replicas and 700 plaster casts of mollusca, and 30 thin sections of corals.

At the Acid Laboratory, Fyshwick, 2500 samples totalling 2300 kg of rock were processed for the extraction of conodonts, and 1500 samples picked for conodonts.

Other activities of the Palaeontology Laboratories included the photographing of microfossils and macrofossils, the printing of photographic plates for publication, the cataloguing and labelling of specimens for the Museum, the packing and sending of loan material to institutions, the transferring of information to BMR code forms, and the proof-reading of galleys.

CONFERENCES ATTENDED

The following conferences were attended by members of the section:

Fifth Australian Geological Convention, Perth, August: M.J. Jackson, J.F. Marshall, R.V. Burne, P.J. Jones, R.S. Nicoll

Hydrology and Water Resources Symposium, Institute of Engineers, Adelaide, November: M.A. Habermehl

Fifty-first ANZAAS Congress, Brisbane, May: C.J. Simpson

Landsat 81 Conference, Canberra, September: C.J. Simpson, W.J. Perry

Fifteenth Newcastle Symposium on advances in the study of the Sydney Basin: A. Brakel, P. O'Brien, J.M. Dickins

Thirteenth International Botanical Congress, Sydney, August: D. Burger, E.M. Truswell

The Cainozoic Evolution of Continental Southeast Australia, Canberra, November: R.S. Abell, E.M. Truswell, L. Harrington, G.E. Wilford, C.M. Brown

Second International Symposium on the Cambrian System, Colorado, USA, August: J.H. Shergold

Antarctica; Weather and Climate, Melbourne, May: E.M. Truswell

APEA Conference, Adelaide, April: G.E. Wilford

AAPG Annual Conference, San Francisco, USA, June: H.F. Doutch

Australasian Sedimentologist Group 1980 Conference, Canberra, December: A. Brakel, B. Radke

Geology and Colliery development in the Western Coalfield, NSW, Sydney, March: A. Brakel, L. Harrington

Coastal lagoons of NSW, Sydney, July: R.V. Burne

Fourth International Coral Reef Symposium, Manila, Philippines, May: P.J. Davies

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

Supervising Geologist: R.G. Dodson

ARUNTA PROJECT

by

R.D. Shaw

STAFF: Full-time - R.D.Shaw

Part-time - L.A. Offe, A.J. Stewart, A.Y. Glikson, and R.G. Warren (BMR)

- M.J. Freeman and C.L. Horsfall (Northern Territory Geological Survey)

AIMS:

The objectives of the Project are to obtain, study, and make available basic geological and economic mineral data on the Arunta Block to provide a basis for the understanding of the region's mineral resources.

REPORTING AND PROGRESS OF MAP PRODUCTION

This year's activities have centred on map production and report writing. The main results of the year's work are:

1. Printing of the composite REYNOLDS RANGE REGION 1:100 000 First Edition special map.
2. Printing of Preliminary 1:100 000 maps of MACDONNELL RANGES and RIDDOCH. Preliminary maps of DNEIPER, JINKA, JERVOIS RANGE, QUARTZ, LIMBLA, GLEN HELEN, ANBURLA, and NARWIETOOMA are in various stages of drafting.
3. Release of compilation sheets at 1:25 000 scale of QUARTZ, LIMBLA, and DNEIPER.
4. Preparation of the composite 1:100 000 HARTS RANGE-ARLTUNGA REGION First Edition map and Commentary.
5. Release of a microfiche Record on the 1:100 000 and 1:250 000-scale mapping in the northern Arunta Block (Record 1980/63).
6. Publication of the Report 'Tectonic setting of easternmost Arunta Block' (Report 221) and the release of the Record 'The Arunta Block in the Huckitta 1:250 000 Sheet area: a review of data to June 1980' (Record 1980/45).

METALLIFEROUS SECTION

Head: K.R. Walker

7. Presentation of two complementary papers on the stratigraphy and tectonics of the Arunta Block during the International Conference on Deformation Processes in Tectonics organised by GSA (SGTSG) and held in central Australia in August. A third paper was given at the same conference on the relationship between retrograde metamorphism and faulting in the Strangways Range.

DATA PRESENTATION

ALICE SPRINGS 1:250 000 SHEET AREA

Map editing was completed on the 1st Edition 1:250 000 map and the Explanatory Notes are with the text editors. The composite 1:100 000 special map of ALICE SPRINGS REGION is being fair-drawn, and the Commentary is with the editors. Composite 1:100 000 special maps and Commentaries of STRANGWAYS RANGE and ARLTUNGA-HARTS RANGE REGIONS are with the editors. The Record (1980/44) 'Summary descriptions of mineral deposits by commodities in the Alice Springs 1:250 000 Sheet area, Northern Territory', was released in November 1980.

HERMANNSBURG 1:250 000 SHEET AREA

The MACDONNELL RANGES 1:100 000 Preliminary map has been released. Photo-overlays have been passed on to the drawing office for GLEN HELEN and part of NARWIETOOMA. ANBURLA has been compiled in draft form. Probe work on granulites has commenced.

NAPPERBY 1:250 000 SHEET AREA

The special 1:100 000 1st Edition map of REYNOLDS RANGE REGION has been released and the Commentary is with the printer. The detailed microfiche Record on 1:250 000 and 1:100 000-scale mapping in the northern Arunta Block was released. The 2nd Edition NAPPERBY 1:250 000 map is being fair-drawn and the Explanatory Notes are with the editor.

ILLOGWA CREEK 1:250 000 SHEET AREA

Compilation sheets at 1:25 000 have been released of QUARTZ and LIMBLA. The draft of the Record on 1979-80 fieldwork is being revised.

Preparation of the Second Edition 1:250 000 map commenced and a draft has been written of the Explanatory Notes.

HUCKITTA CREEK 1:250 000 SHEET AREA

Compilation sheets of DNEIPER have been released, and compilation sheets covering basement rocks in JERVOIS RANGE and JINKA should be released shortly. A draft Record on 1980 fieldwork is being revised. Petrological studies are underway on the granulites from the eastern part of the region. These rocks have been hydrated in several stages under a series of decreasing PT conditions.

MISCELLANEOUS ACTIVITIES

Mathur (Geophysical Branch) & Shaw gave a BMR talk on 'Geosutures and mobile belts in Australia'. The talk was repeated by Shaw to the Central Australian Earth Science Group (GSA & AIMM) in Alice Springs. Shaw, Stewart, & Black presented two companion papers on the 'Geological evolution of the Arunta Block: Stratigraphy and Tectonics', at the International Conference on Deformation Processes in Tectonics held at Glen Helen, Alice Springs in August. They also led a pre-conference field excursion and together with Offe, acted as guides to several localities visited during the conference. Warren also presented a paper, entitled 'Retrograde metamorphism related to major fault zones at the northern margin of the Strangways Range'. She has been on study leave since March. Shaw spent three weeks with the Davenport Geological Party collecting data on the physical properties of rocks to be used in interpretaion of regional geophysical data.

DARWIN OFFICE

by

C.E. Prichard

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

Eighteen motor vehicles and eleven trailers were stored at the Tannadice Street Store after the 1980 field season. A party mechanic checked and repaired the vehicles before the 1981 field season. The new lockable party bays for party stores proved a big improvement in keeping stores of various parties separate. During the year the septic system was replaced by connection to sewer and one of the rooms in the store building was prepared to house the seismic recorders.

The Woods Street office was occupied throughout the year but is expected to be vacated shortly as the area is required by the NT Government. Sales of publications and maps averaged 160 per month - an increase of 23% on last year. Use of the reference facility by prospectors, companies, and the general public also increased. Many of the sales and most reference searches included geological discussion and advice. The Senior Geologist represented the Bureau on the mining industry stand at Careers Night for Darwin High School students.

Permits to enter Aboriginal Land were arranged for members of one field party and the airborne party was assisted in location of vehicles for their operations. All parties operating in the area received support and assistance as required. The Senior Geologist was a member of interview committees for Land Surveyor Class 2 (Australian Survey Office) and Inspector Audit Class 8 (Central Office).

Cyclone Max struck Darwin in March but, unlike its predecessor Tracy, caused no appreciable damage.

Various senior Bureau officers and overseas visitors connected with the Bureau were assisted with local arrangements including visits to the Rum Jungle area and The Alligator Rivers Uranium Field.

A geological field inspection of the Litchfield area arranged by Mobil Energy Minerals was attended by the Senior Geologist.

The Manton Seismic Station was maintained in operation except for two weeks following a fire in the power and timing monitor. Minor periods of lost record or noisy record were due to land line malfunctions. Preliminary interpretation of records of both Manton and Alice Springs stations continued. First arrivals for both stations were telexed to the Observatory Section several times a week. The room at Tannadice Street has had RAC, power points, etc., fitted and an aerial has been erected, ready for the location of the recorders there.

DAVENPORT GEOSYNCLINE PROJECT

by

D.H. Blake

STAFF: D.H. Blake; A.J. Stewart; C.L. Horsfall (NTGS); S. Wyche (NTGS); C.P. Knight (draftsman); K.J. Armstrong (camp manager).

AIMS

1. To determine the detailed stratigraphy, structure, geological history, and mineral potential of the Precambrian Davenport Geosyncline.
2. To determine how the Arunta region to the south is related geologically to the Tennant Creek region to the north, and hence help elucidate the tectonic setting and crustal evolution of this part of central Australia.
3. To provide a framework for interpreting the subsurface geology of the western margin of the Georgina Basin and the eastern margin of the Wiso Basin.

INTRODUCTION

The Davenport Geosyncline region links the Precambrian Arunta and Tennant Creek regions, lies between the mainly Lower Palaeozoic Georgina and Wiso Basins, and contains W, Cu, Au, Pb, Ag, and U mineral deposits. However, it has received relatively little attention from geologists, and the only previous systematic geological investigation of the region was a broad reconnaissance survey by BMR in 1956.

Work on the project commenced in 1981 with a 4-month field season. A field season of similar length is planned for 1982, and fieldwork is expected to be completed in 1983. Final reports, maps, and research papers should be completed by mid-1985.

FIELD ACTIVITIES

Fieldwork was carried out from 2 June to 2 October 1981 by Blake, Stewart, Horsfall, and Wyche in HATCHES, MURRAY DOWNS, much of DAVENPORT RANGE, northwestern part of HANLON, and southernmost parts of OORADIDGEE and EPENARRA (Fig. M1), in the central part of the Davenport Geosyncline. The remainder of

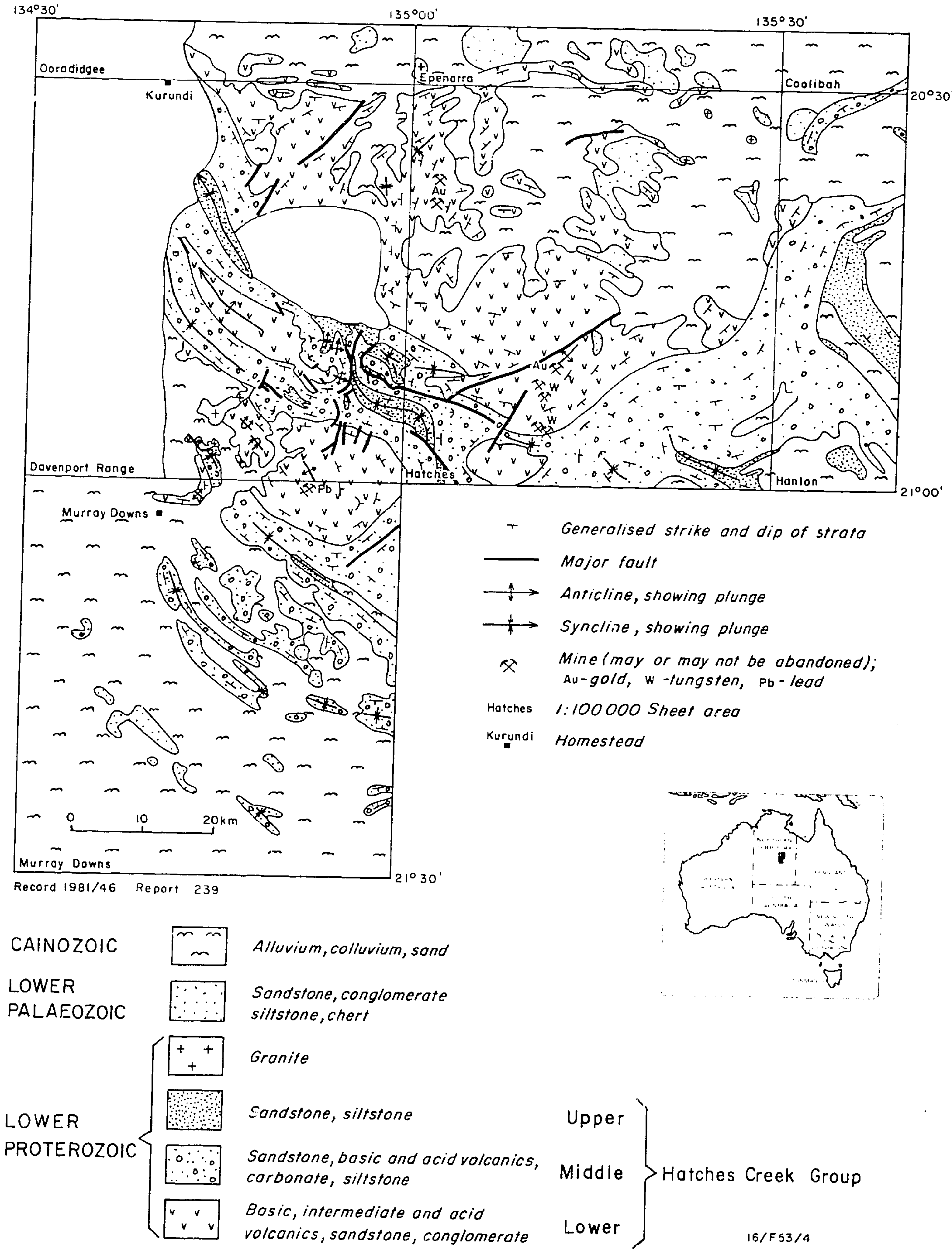


Fig M1 Generalised geological map of central part of Davenport Geosyncline the region, in DAVENPORT RANGE, BONNEY, WAUCHOPE, ELKEDRA, and HANLON, will be examined during the 1982 field season.

GENERAL GEOLOGY by D.H. Blake, A.J. Stewart, C.L. Horsfall, & S. Wyche.

The oldest rocks exposed in the area investigated belong to the Precambrian Hatches Creek Group. This group, which is probably at least 10 000 m thick in places, is made up of ridge-forming sandstone units interlayered with less resistant sedimentary and volcanic rocks (commonly deeply weathered and recessive). The sedimentary rocks consist largely of detrital quartz derived from outside the region, and feldspar (generally altered), mica, lithic clasts, and kaolinitic material which are thought to mainly represent locally derived volcanic detritus; some carbonates and evaporites are also present. Most ridge-forming sandstones consist mainly of quartz, whereas recessive sandstones are generally feldspathic and commonly have a relatively abundant clayey or micaceous matrix. Cross-bedding, ripple marks, convolute bedding, and related structures, rare mud-cracks, moulds and casts of gypsum and halite, and the presence in one unit of stromatolites indicate that most, if not all, the sediments were deposited in shallow water. The volcanic rocks include lavas and pyroclastics which range in composition from rhyolite to basalt, and were erupted either subaerially or into shallow water.

The Hatches Creek Group is intruded by gabbro, dolerite, granophyre, granite, quartz-feldspar porphyry, and 'microsyenite', is folded into open to very tight major anticlines and synclines, is extensively faulted, is regionally metamorphosed mostly to only lower greenschist grade, and is locally cleaved (mainly near fold axes and major faults). It is overlain by flat-lying Lower Palaeozoic (mostly Cambrian) sedimentary rocks (mainly conglomerate but also some chert and fossiliferous siltstone and sandstone), and surficial Cainozoic deposits. Granite intruding the group has been isotopically dated (K-Ar method) at 1540-1320 m.y. (Smith & others, 1961, BMR Report 58)

Stratigraphy of the Hatches Creek Group

The Hatches Creek Group is provisionally subdivided into lower, middle, and upper parts. The middle and upper parts show a general 'layer cake' stratigraphy in the area mapped, whereas in the lower part the various rock units interfinger laterally with one another. No local or regional unconformities have been positively identified in the sequence. A total of 19 informally named formations and two members have been recognised, and are briefly described below; their relationships are shown diagrammatically in Figure M2.

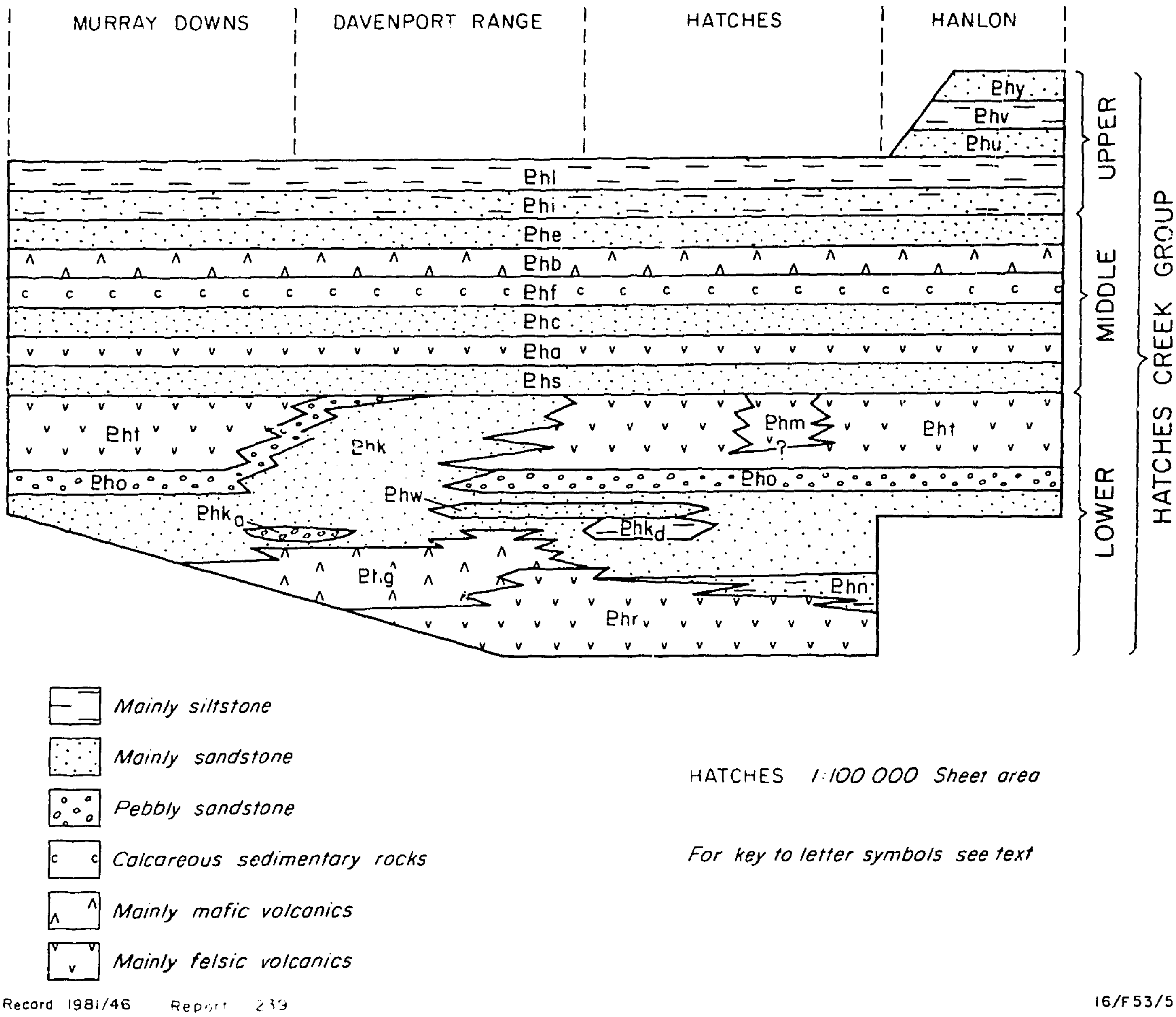


Fig. M2 Diagrammatic relationship of rock units within the Hatches Creek Group

Lower Hatches Creek Group

Phr, Epenarra volcanics: over 1000 m thick, base not exposed; consist of recessive, locally cleaved, felsic lavas and coarse to fine pyroclastic rocks, and, mainly in the upper part, interlayered ridge-forming quartzose to volcaniclastic sandstone and conglomerate.

Phn, Rooneys formation: probably about 500 m thick; generally recessive; consists mainly of thin-bedded to laminated ?tuffaceous sandstone and siltstone, tentatively taken to include mica schist exposed in northeast HATCHES.

Phg, Edmirringee volcanics: maximum thickness at least 1000 m; consists of generally recessive mafic and minor felsic lava flows.

Phk, Kurinelli sandstone: maximum thickness probably more than 2000 m; consists mainly of ridge-forming quartzose to feldspathic sandstone and recessive friable sandstone, siltstone, and laminated tuff; minor felsic to mafic volcanic rocks and also evaporitic claystone are present locally near base.

Phk_a, Kaidwalla conglomerate member of the Kurinelli sandstone: about 300 m thick; consists mainly of low ridge-forming pebble to boulder conglomerate with a distinctive bluish grey sandstone matrix, grading up into coarse sandstone; some interbedded shale and clayey sandstone are also present.

Phk_d, Endurance sandstone member of the Kurinelli sandstone: about 300 m thick; a recessive unit consisting of thin-bedded to laminated grey micaceous sandstone and siltstone.

Phw, Warnes sandstone: about 500 m thick; forms knobbly ridges of mainly non-bedded, poorly sorted sandstone (primary bedding possibly destroyed by penecontemporaneous earthquakes).

Pho, Taragon sandstone: maximum thickness about 500 m; consists of ridge-forming sandstone, pebbly sandstone, and conglomerate.

Pht, Treasure volcanics: maximum thickness about 2000 m; consists of generally recessive felsic lava, together with minor pyroclastic rocks and mafic lava, and subordinate interlayered ridge-forming sandstone.

Phm, Mia Mia volcanics: probably more than 200 m thick, base not exposed; consists of recessive, commonly leaved, felsic lavas and pyroclastics, and, mainly near the top, minor interlayered ridge-forming sandstone.

Middle Hatches Creek Group

Phs, Unimbra sandstone: up to about 1000 m thick; consists of ridge-forming sandstone.

Pha, Arabulja volcanics: average thickness about 500 m; a generally recessive unit consisting of felsic lava, pyroclastic rocks, volcaniclastic sedimentary rocks, and minor ashstone.

Phc, Coulters sandstone: average thickness about 800 m; consists of ridge-forming sandstone.

Phf, Frew River formation: generally less than 500 m thick; a recessive unit consisting of thin-bedded sandstone and siltstone with some halite casts, mainly in the lower part, and calcareous and dolomitic beds which in places contain stromatolites, including Conophyton, mainly in the upper part.

Phb, Kudinga basalt: generally less than 500 m thick; consists of recessive basaltic lava flows, minor interlayered ridge-forming sandstone, and rare pillow basalt.

Phe, Errolola sandstone: average thickness about 800 m; consists of ridge-forming sandstone.

Upper Hatches Creek Group

Phi, Alinjaborn sandstone: about 500 m thick; consists of two or three bands of ridge-forming sandstone separated by recessive friable feldspathic sandstone, siltstone and shale.

Phl, Lennee Creek formation: about 1800 m thick; a recessive unit consisting of interbedded feldspathic sandstone, siltstone, and shale.

Phu, Canuigera sandstone: about 800 m thick; consists of ridge-forming sandstone and interbanded recessive siltstone.

Phv, Vaddingilla formation: about 700 m thick; consists of recessive feldspathic and micaceous sandstone and siltstone which may be tuffaceous.

Phy, Yaddanilla sandstone: about 700 m thick; consists of ridge-forming sandstone.

Igneous intrusions

Igneous intrusions are most common within the lower Hatches Creek Group, and none have been recorded in units younger than the Arabulja volcanics. They generally crop out in depressions. Gabbro and dolerite commonly form multiple sills with internal chilled margins and thin screens of country rock; granophyre, quartz-feldspar porphyry, and 'microsyenite' also form sills, mainly within felsic volcanic sequences. These intrusions appear to predate folding, and may be genetically related to the volcanics of the Hatches Creek Group. Muscovite and biotite-bearing granites, some containing feldspar phenocrysts, intrude Epenarra volcanics and Rooneys formation in the north and Kurinelli sandstone and Mia Mia volcanics in the south; at least some of the granite intrusions appear to postdate the folding of the Hatches Creek Group.

Mineralisation

Tungsten: several old tungsten mines are present in southwest HATCHES, where wolframite and subordinate scheelite occur in quartz veins cutting Treasure volcanics and older units. The veins, which also contain minor Cu, Bi, and Mo, appear to postdate folding and may be related to a concealed granite.
Copper: as well as being present in W-bearing quartz veins, copper minerals also occur in amygdales in mafic lavas within the Hatches Creek Group and in gabbro, dolerite, and granophyre intrusions.
Gold: gold has been obtained at several localities from auriferous quartz veins cutting gabbro, dolerite, and associated country rocks.
Silver and Lead: galena has been mined in north MURRAY DOWNS, where it occurs in quartz veins cutting basalt and dolerite; galena is also present nearby in amygdales in basalt.

HATCHES CREEK GROUP VOLCANISM by D.H. Blake

Volcanic rocks ranging in composition from felsic (rhyolite, dacite, and andesite) to mafic (basalt and basaltic andesite) are widespread within the lower and middle Hatches Creek Group. They include quartz-feldspar porphyries previously thought to be intrusive, and rocks in the north which were regarded as belonging to the Warramunga Group. The oldest exposed, those of the Epenarra volcanics, are mainly felsic, and were probably erupted from a major volcanic centre in the north. Overlying amygdaloidal and scoriaceous mafic lavas of the Edmirringee volcanics appear to have formed a volcanic edifice more than 1000 m high in northeast DAVENPORT RANGE. Lavas on the flanks of this volcano interfinger with Kurinelli sandstone to the east. Mafic lavas of apparently similar age exposed in south DAVENPORT RANGE and the adjoining part of MURRAY DOWNS were probably derived from a different volcanic centre. A return to felsic volcanism is represented by the Treasure volcanics, a unit of felsic lavas and pyroclastic rocks (similar to those of the Epenarra volcanics), and minor mafic lavas (in west HATCHES). The Treasure volcanics may have come from the volcanic centre represented by the Mia Mia volcanics in southwest HATCHES or from another centre which is not exposed. Following a period of clastic sedimentation, during which the Unimbra sandstone was deposited, felsic volcanism resumed with the eruption of lavas and pyroclastic rocks of the Arabulga volcanics. The Coulters sandstone separates this felsic unit from the overlying Kudinga basalt, an extensive unit of mafic lavas. The youngest volcanic rocks exposed are andesitic? lavas present in places near the top of the Errolola sandstone.

Units of mafic lavas are generally more extensive than those of felsic volcanics, which tend to thin out more rapidly along strike, their place being taken by variably tuffaceous and volcaniclastic sedimentary rocks. The mafic lavas are generally amygdaloidal and scoriaceous, locally contain feldspar phenocrysts, and commonly have autobrecciated margins; pillows have been found at two localities, in southeast DAVENPORT RANGE. Common features of the felsic lavas are contorted flow-banding, platy jointing, fissured tops infilled with sandstone, spherulitic textures, and small phenocrysts of felspar, quartz,and, in some cases, ferromagnesian minerals. Felsic pyroclastic rocks present include laminated to massive tuff, lapilli tuff, coarse agglomerate, and ashstone, but not, apparently, any ignimbritic deposits.

The mafic lavas are generally somewhat chloritised and epidotised, but have well-preserved primary igneous textures. The felsic volcanics are also commonly altered, partly owing to penecontemporaneous hydrothermal activity and partly to Cainozoic weathering, but appear quite fresh in places.

The volcanic rocks of the Hatches Creek Group are derived from several volcanic centres partly separated from and partly overlapping one another in time and space. The mafic and felsic sills common in the lower part of the Hatches Creek Group may be comagmatic with the volcanics, and their emplacement may have accompanied the volcanism. The petrologic affinities and tectonic setting of the volcanic and intrusive rocks have yet to be determined.

SPECULATIONS ON THE STRUCTURAL EVOLUTION OF THE DAVENPORT GEOSYNCLINE by A.J. Stewart.

MACROSCOPIC STRUCTURES

Domes

At least three large domes are present; they are located in the southwest of HATCHES, the northwest of ELKEDRA (not shown in Fig. M1), and straddling MURRAY DOWNS and DAVENPORT RANGE (Fig. M1). Strata of the middle Hatches Creek Group (Phm) dip moderately to steeply off cores of volcanic and sedimentary rocks of the lower Hatches Creek Group (Phl). Cleavage is weak to moderate. No basement is known in the cores of the domes.

Tight elongate folds

The Davenport Geosyncline is characterised by large anticlines and synclines with northwest to southwest trends, upright or steeply inclined axial surfaces, and gentle to steep plunges. There are also smaller folds, some with plunges greater than 90^{o}, forming antiformal synclines. Axial-plane cleavage is common, and is strongest in the fold hinges; the cleavage is fanned around the axial planes, and is refracted as it passes from slaty to sandy beds. Fold mullions, formed by the intersection of cleavage and small crumples in the bedding, are present in some hinge zones. Only the lower Hatches Creek Group is exposed in the cores of the anticlines.

In the southeast DAVENPORT RANGE (Fig. M3a), detailed mapping has shown that north-trending folds on the northern flank of the major northwest-trending anticline in the area formed during a later episode of deformation; cleavage belonging to the earlier northwest-trending fold is folded, and towards the axial region of the later fold it is overprinted by a second axial-plane cleavage. In the transition zone, the beds exhibit two intersecting slaty cleavages.

Faults

Most are straight, and formed after the major folding of the region. Several markedly curved faults in southeast DAVENPORT RANGE formed early in the folding.

Flexures adjacent to major faults

These have very steep axes and axial planes (Fig. M3d), and formed by drag during movement along the faults.

MESOSCOPIC STRUCTURES

Open elongate folds in Kurinelli sandstone

The lower part of the Kurinelli sandstone in the large dome straddling DAVENPORT RANGE and MURRAY DOWNS is markedly contorted into numerous open elongate folds which are upright, trend generally northwest, and have gently curved axial planes and gentle to moderate northwesterly plunges. Small disharmonic folds (Fig. M3b) are present in places in the same unit. The presence of halite-bearing claystone in this part of the unit may account for the contortions and the decollement-style of folding.

Box folds

These are present in the upper part of the Kurinelli sandstone in southeast DAVENPORT RANGE (Fig. M3c). They have steep axes and upright axial planes, and deform any cleavage present.

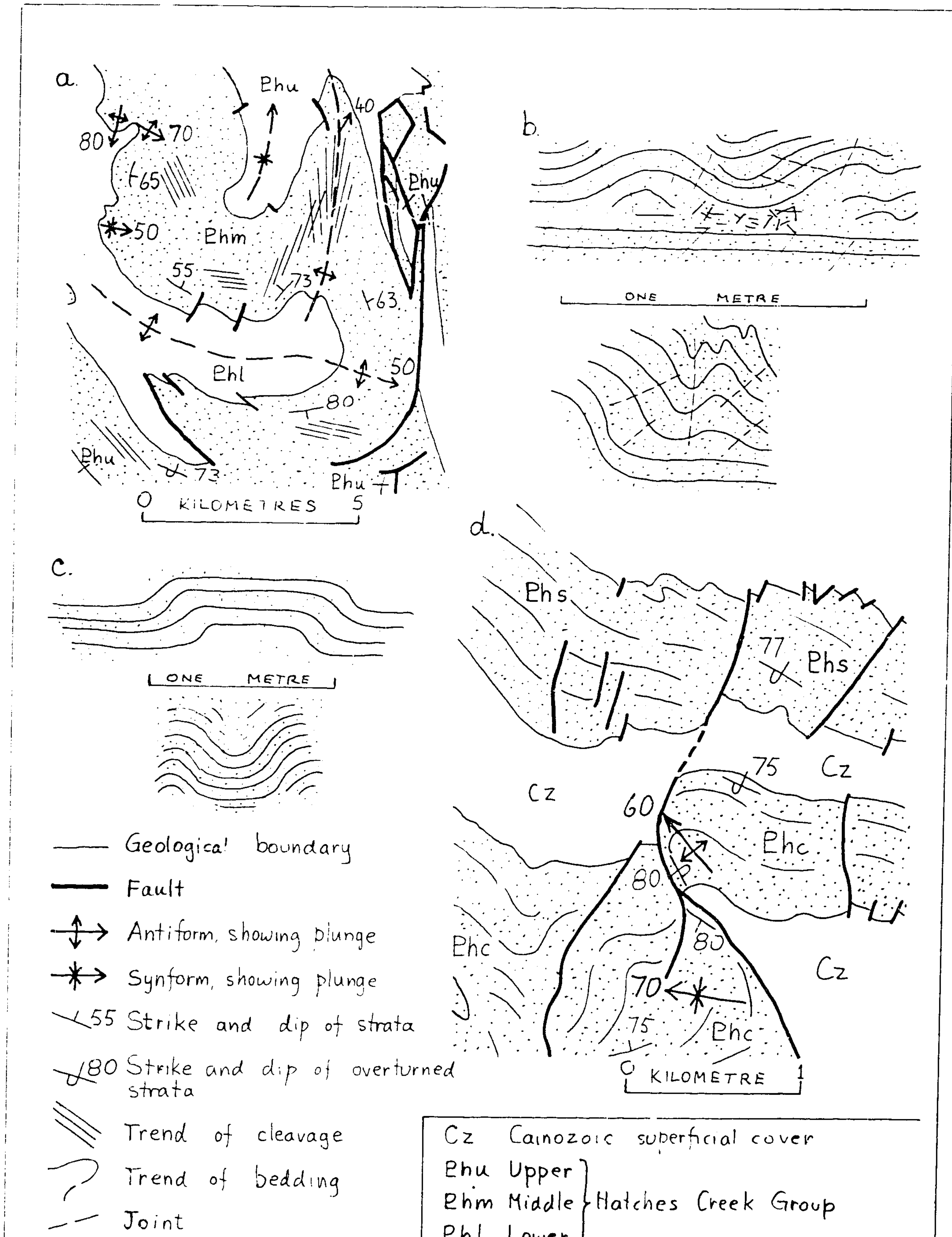


Fig. M3 - Sketches of structures in Hatches Creek Group, southeast DAVENPORT RANGE. a. Tight elongate folds showing early NW-trending fold and cleavage, overprinted by later N-trending folds with fanned cleavage. b. Disharmonic folds in lower part of Kurinelli Sandstone. c. Conjugate box folds in upper part of Kurinelli Sandstone. d. Flexures adjacent to vertical faults in Unimbra Sandstone (Ehs) and Coulters Sandstone (Ehc).

Cleavage

In addition to axial-plane cleavage, a late fracture cleavage is also present in many areas, especially near and parallel to faults. It is particularly common in sandstone, where it generally cuts across folds at a large angle.

Fractures

These are very common in sandstone, are spac . a few centimetres apart, and form two or three intersecting sets. Where the fracturing is intense, bedding is obliterated.

EVOLUTION

The absence of any recognisable basement in the cores of anticlines in the Davenport Geosyncline, and the presence of halite-bearing claystone low in the sedimentary sequence, suggest the possibility of a decollement near the base of the Hatches Creek Group. However, it is also possible that the lithological similarity of the Warramunga Group, which may underlie the Davenport Geosyncline and the Hatches Creek Group (both consisting largely of interbedded sandstone and volcanic rock), has resulted in there being no great contrast in mechanical properties of the two groups. The piles of volcanic rock low in the Hatches Creek Group - the volcanic edifices - may have become effectively welded too and thus subsequently acted as 'basement' during deformation of the overlying part of the Hatches Creek Group; they may have acted as relatively rigid blocks, around which the sedimentary rocks crumpled and broke.

The first structures to form were the large domes, the tight elongate major folds with axial-plane cleavage and mullions, and possibly the smaller open elongate folds in the Kurinelli sandstone. The general orientation of the folds indicates that the principal compressive stress was oriented northeast-southwest. The gently arcuate shapes of the axial surfaces of the folds, and the variation in trend of the axial surfaces throughout the geosyncline, may be a result of the heterogeneous nature of the deforming rocks combined with variation in the regional stress field, rather than the result of separate episodes of folding. The folds were simply forced to accommodate themselves to the space available between the more rigid volcanic blocks. Hence, the 'later' north-trending folds in southeast DAVENPORT RANGE (Fig. M3a), and the steep to oversteepened fold axes nearby, may be merely the later stage of one very heterogeneous major folding event. The conjugate box folds (Fig. M3c) and flexures adjacent to faults (Fig. M3d), however, appear to be significantly younger, and represent a relatively minor deformation, with a northerly principal compressive stress.

PINE CREEK GEOSYNCLINE PROJECT

by

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

STAFF: R.S. Needham (project leader), I.H. Crick, P.G. Stuart-Smith, D.A. Wallace (to April), L. Bagas, (NTGS) I.C. O'Donnell, J. Gallagher (draftsmen).

AIMS

The objectives of the project are:

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

INTRODUCTION:

The project encompasses the following major tasks:

Study of the geology and mineralisation of the Alligator Rivers Uranium Field.

Study of the geology and mineralisation of the Rum Jungle Uranium Field.

Study of the geology and mineralisation of the South Alligator Valley Uranium Field.

Study of the Early Proterozoic stratigraphy of the Pine Creek Geosyncline.

Study of the geology and mineralisation of the Cullen Mineral Field.

Study of Early Proterozoic evaporites and their role in uranium ore genesis.

Synthesis of the geology and mineralisation of the Pine Creek Geosyncline.

To date, twenty-one 1:100 000 Sheet areas have been covered by semi-detailed fieldwork; thirteen Preliminary standard series 1:100 000 maps and three Preliminary special 1:100 000 maps have been issued, and three more standard series Preliminary maps are at an advanced stage of production. Two First Edition coloured 1:100 000 geological maps have been issued and one more standard series and three specials are in progress. One Preliminary to a Second Edition 1:250 000 map has been issued and the Second Edition is in progress. Field compilation sheets, mainly at 1:25 000 and 1:50 000 scale, are available for all areas investigated to date. During 1981, emphasis has been on petrological studies of rocks from PINE CREEK; on fieldwork in RANFORD HILL, STOW, and NOONAMAH; on the study of granites and mineralisation in the Cullen Mineral Field; and on the preparation of maps, map Commentaries, and Explanatory Notes for the Alligator Rivers Uranium Field.

With current manpower the geological investigations and reporting will be completed in about 4 years.

REPORTING AND PROGRESS OF MAP PRODUCTION

Progress of map production is shown in the Frontispiece and in Figure M4. The McKINLAY RIVER, MARY RIVER/POINT STUART, and BATCHELOR/HAYES CREEK 1:100 000 Preliminary maps were issued during the year. Checking of the final draft of the PINE CREEK Preliminary is in progress. CAHILL has been issued as a First Edition and NABARLEK, MUNDOGIE, and MARY RIVER/POINT STUART are in preparation; map Commentaries have been prepared for these and are being edited. The First Edition ALLIGATOR RIVER has been issued as a Preliminary, and the coloured edition and Explanatory Notes are being edited. A Bulletin describing the geology of the Alligator Rivers Uranium Field is being prepared. A data Record containing compilation sheets and thin section descriptions from McKINLAY RIVER was issued, and a Record describing the geology of MARY RIVER/POINT STUART is in press. A Record tabulating brief descriptions of the mineral occurrences of the Pine Creek Geosyncline was also issued.

RUM JUNGLE URANIUM FIELD by I.H. Crick.

Final corrections and preparation of RUM JUNGLE were completed and a Second Edition Preliminary map has been issued. A revised stratigraphic interpretation of this area and to BATCHELOR/HAYES CREEK (see below) were reported in the 1980 Annual Summary (BMR Report 230).

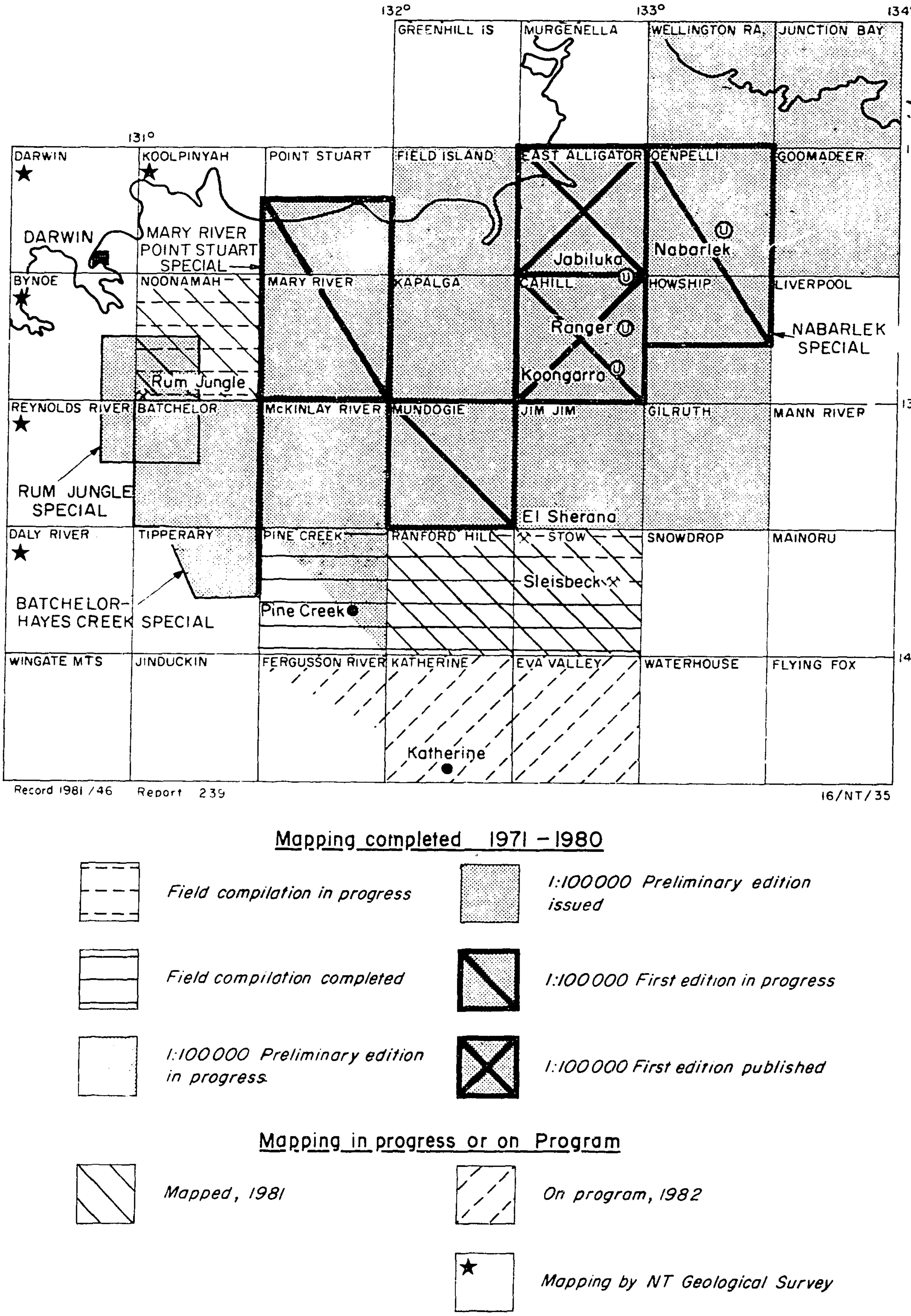


Fig. M4 Progress of geological mapping and index to 1:100000 Sheet areas, Pine Creek Geosyncline Project.

SOUTH ALLIGATOR VALLEY URANIUM FIELD by P.G. Stuart-Smith, R.S. Needham, L. Bagas (NTGS).

The South Alligator Valley Uranium Field lies in the northwestern part of STOW and southeastern part of MUNDOGIE, and consists of an extensively faulted belt of Lower Proterozoic metasediments overlain unconformably by the Carpentarian Edith River group*, Big Sunday volcanics*, and, in places, Kombolgie Formation. Lower Proterozoic units present in STOW are the Masson Formation, Stag Creek Volcanics, Mundogie Sandstone, Koolpin Formation, Mount Bonnie Formation, and Zamu Dolerite. Northwest-trending faults dominate the structure of the area and have significantly influenced sedimentation in the basal Big Sunday volcanics,* as indicated by marked thickening of volcanics and the appearance of sandstone lenses in fault-bounded troughs.

Those mines and prospects within STOW were examined, and field research in the uranium field is now complete. Literature research continued, and initially the information will be incorporated in the Record on the geology of STOW.

LOWER PROTEROZOIC STRATIGRAPHY OF THE PINE CREEK GEOSYNCLINE by P.G. Stuart-Smith, R.S. Needham, I.H. Crick, L. Bagas (NTGS)

This project included field research in areas of Lower Proterozoic metasediments in STOW and RANFORD HILL, and petrological, mineralogical, structural, and metamorphic studies of rocks from PINE CREEK. These studies have largely confirmed and extended the stratigraphy defined in MUNDOGIE, McKINLAY RIVER, and MARY RIVER.

STOW AND RANFORD HILL 1:100 000 SHEET AREAS by P.G. Stuart-Smith, R.S. Needham, L. Bagas (NTGS).

Field research into Lower Proterozoic metasediments in STOW and RANFORD HILL was completed during 1981. The area contains isoclinally folded northwest-trending Lower Proterozoic metasediments which are unconformably overlain by Carpentarian, Cretaceous, and Cainozoic sediments (Fig. M5). The metasediments are intruded by pre-orogenic Zamu Dolerite dykes and sills, four Carpentarian granites (the Cullen, Mount Diamond, Wofram Hill, and Malone Creek Granites), Oenpelli Dolerite dykes, and by minor post-orogenic felsite, porphyry, and dolerite dykes.

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* informal name

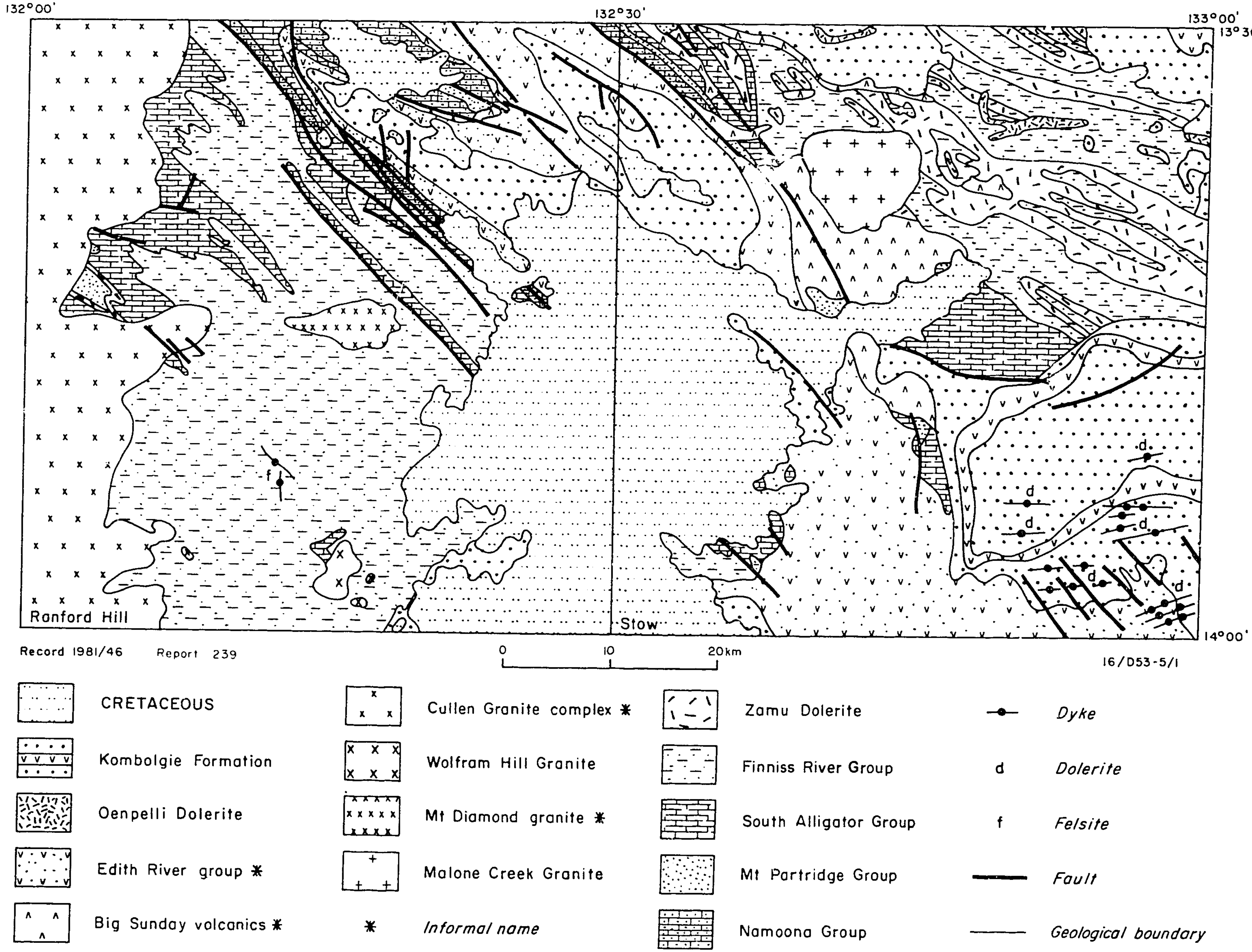

Fig. M5 Solid geology, Ranford Hill and Stow 1:100 000 Sheet areas, Pine Creek Geosyncline

The Lower Proterozoic stratigraphy established over recent years in other parts of the Pine Creek Geosyncline has been extended into the area. Units present are the Namoona, Mount Partridge, South Alligator, and Finniss River Groups. Areas previously mapped as Golden Dyke Formation have been included in the South Alligator Group, as well as some areas previously mapped as Burrell Creek Formation (Finniss River Group).

The Masson Formation (Namoona Group) extends farther south than previously mapped, and occupies an intensely faulted and isoclinally folded northwest-trending belt along the western margin of the Carpentarian Callanan Basin. Similar long linear northwest-trending faults are common throughout the Lower Proterozoic sequence, particularly in the South Alligator Valley where they show repeated movement in the overlying Carpentarian and Cretaceous sediments.

Significant changes in the correlation of Carpentarian units have been made (Fig. M6). The Plum Tree Creek volcanics* and Kurrundie sandstone* are now considered to comprise, along with the Phillips Creek sandstone*, the Edith River group*. Areas previously mapped as Grace Creek Granite consist of rhyolite, rhyodacite, ignimbite, tuff, and intrusive equivalents, and are correlated with the Plum Tree Creek volcanics. Previous workers had mapped weathered varieties of these rocks, particularly near the Carpentarian unconformity, as Edith River Volcanics.

The Pul Pul Rhyolite and Coronation Sandstone members are now considered to be older than the Edith River group and comprise part of the Big Sunday volcanics*. The relationship between the Big Sunday volcanics and the overlying Edith River group appears to be conformable in most places but an angular discontinuity is present about 7 km southeast of Coronation Hill.

PINE CREEK 1:100 000 SHEET AREA by P.G. Stuart-Smith

Petrological, mineralogical, structural and metamorphic studies of rocks from PINE CREEK commenced. Greywackes and conglomerates in the Burrell Creek Formation were found to be volcanolithic, commonly containing clasts of pitchstone, tuffaceous chert, rhyolite, and crystal tuff. Previously unidentified lenses of rhyolite and trachyandesite are interbedded with greywackes of the same Formation near Union Extended.

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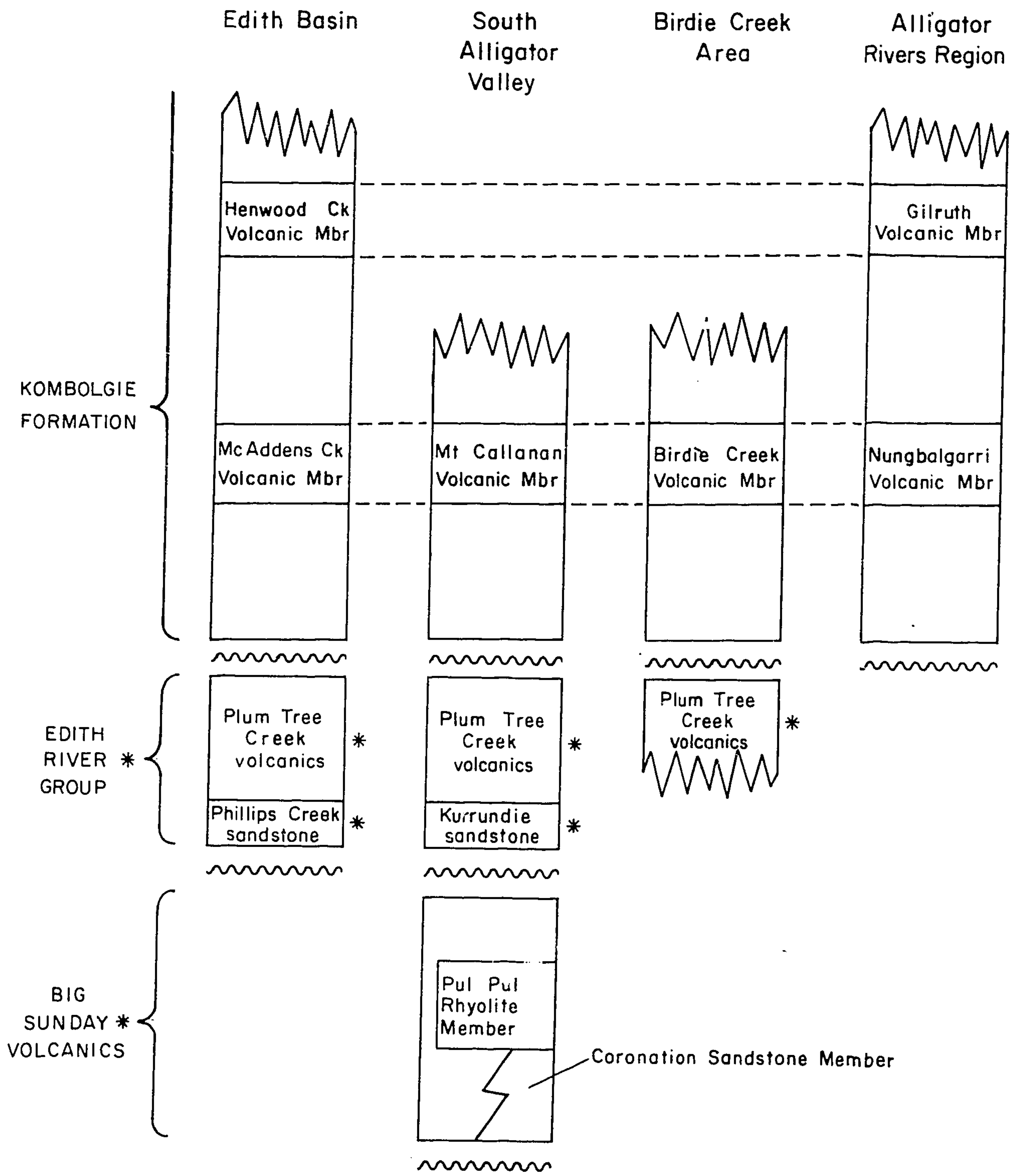
* informal name



Record 1981/46 Report 239 16/NT/36

Unconformity

* *Informal name*

Fig. M6 Correlation and revised stratigraphic nomenclature of Carpentarian volcanic units in the Pine Creek Geosyncline

BATCHELOR/HAYES CREEK 1:100 000 SHEET AREA, by I.H. Crick

Compilation of areas of Precambrian rocks in the northeast quadrant of TIPPERARY (Hayes Creek area) were added to the revised BATCHELOR Preliminary Map. The map was issued in October 1981.

NOONAMAH 1:100 000 SHEET AREA by I.H. Crick; E. Dwyer (NTGS)

Additional fieldwork was undertaken in the northern half of NOONAMAH. Compilation is expected to be completed by the end of 1981 and the map issued in 1982. Outcrop is generally sparse in the northern half, and drilling will be required to determine relationships between rock types and units, and to resolve the stratigraphy.

A tightly folded thin quartzite unit displaying scour-and-fill and cross-bedding structures is exposed in places on the Adelaide River flood plain to the north of the Arnhem Highway. This unit is thought to be within the Wildman Siltstone, and is possibly an extension of the Acacia Gap Quartzite Member which crops out to the south of this area.

<u>GEOLOGY AND MINERALISATION OF THE CULLEN MINERAL FIELD</u> by P.G. Stuart-Smith, R.S. Needham; L. Bagas (NTGS).

The Cullen Mineral Field contains most of the base and precious metal occurrences in the Pine Creek Geosyncline. Many of the occurrences are hydrothermal and associated with the intrusion of the Cullen Granite complex* and possibly result from remobilisation of metals in the country rock at or about the time of granite intrusion. This study is designed to investigate the nature of mineralisation and its genesis, by studying the mineral occurrences, their host rocks, and the granite complex. During the year the granites, mines, and mineral occurrences of RANFORD HILL were examined; a geochemical study of the granite phases, alteration and greisen zones, and late dyke rocks was commenced; and collation of information from company and government reports on mining and exploration in the mineral field was continued.

Many of the granite types in the Cullen Granite complex identified in PINE CREEK are present in RANFORD HILL. Several different granite types were also mapped in the Mount Diamond granite* and Wolfram Hill Granite. Numerous zones of greisen and associated tin and tungsten mines are located within the Wolfram Hill Granite and surrounding metasediments of the Burrell Creek and Mount Bonnie Formations.

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* informal name

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

Carbonates from Ranger 3 were examined petrologically and under cathode luminescence. Selected samples were examined under the electron probe. The preliminary results indicate that the major carbonate types are discoidal magnesite and mosaic dolomite. Minor amounts of saddle dolomite - a new type not previously described from carbonates in the Pine Creek Geosyncline - and coarsely crystalline rhombic dolomite, are also present.

The discoidal magnesite is poorly luminescent as it contains minor amounts of iron. It occurs in beds totally made up of this type or is associated with chlorite or mosaic dolomite. In places it has been partly replaced by dolomite. This type of magnesite appears to be pseudomorphous after discoidal gypsum which forms during diagenesis in sabkha-type environments.

The mosaic dolomite is commonly polysynthetically twinned and displays good zonation under electron bombardment in the luminoscope. No corresponding zonation of the trace amounts of Fe and Mn present in this carbonate was detected.

ANTARCTICA

by

R.J. Tingey

STAFF: R.J. Tingey, J.W. Sheraton, L.P. Black, E.M. Truswell, D. Wyborn, J. Shergold, G. Young (Sedimentary Section), Dr P.R. James (University of Adelaide); Mr S. Harley (University of Tasmania).

See also Geophysical Branch Summary of Activities.

- Observatory Group (Mr P. McGregor)
- Regional Studies Group (Dr P. Wellman)
- Marine Section (Mr F.W. Brown)

INTRODUCTION

This summary is confined to BMR Geological Branch activities in Antarctic research; additional information is presented in other relevant Branch Summaries. BMR Antarctic geological investigations are part of an on-going commitment to ANARE research programs.

In 1980 geological fieldwork in Enderby Land was brought to a close after five productive years. During that year also, the Antarctic Research Policy Advisory Committee (ARPAC) became fully operational, particularly in its role of vetting and formulating Antarctic research programs. Many Earth scientists both in BMR and other institutions had hoped to follow the Enderby Land work with similar studies in the Prince Charles Mountains. This has not proved possible because of the increased logistic commitments of the Antarctic Division, Department of Science & Technology, to their station rebuilding program approved by the Parliamentary Committee on Public Works.

Office activities in BMR have centred around the completion or advance of long-standing commitments, work associated with the Antarctic Research Policy Advisory Committee, and projects that have arisen during the year. The 1:500 000-scale geological map of the southern Prince Charles Mountains has now been fair-drawn but the neighbouring northern Prince Charles Mountains Sheet awaits compilation. No progress has been made with projected 1:250 000-scale geological maps of Enderby Land because available LANDSAT base material was judged inadequate: replacement material has been ordered from the United States.

The continuing work of Sheraton and Black is reported elsewhere in the Metalliferous Section report and Wyborn, Shergold and Truswell report their activities in the Sedimentary Section report. Only brief comments are necessary here.

Black's collaborative studies with Dr James and Mr Harley are yielding further insights into the complex geochronological, tectonic, and metamorphic history of the Archaean Napier Complex in Enderby Land, and preparation of various papers is in progress. Sheraton and Black have also studied the intrusive dykes that are used to discriminate between the Napier Complex (which is intersected by the dykes) and the younger Rayner Complex (which is not). A preliminary account of Wyborn's 1980 study of granitoids in northern Victoria Land, undertaken as an Australian participant in the West German GANOVEX expedition, has now been published, but more detailed analytical data are now becoming available.

ANTARCTIC RESEARCH POLICY ADVISORY COMMITTEE

Tingey continued as co-ordinator, Marine and Terrestrial Earth Sciences, for ARPAC during the year. Programs for 1981-82 were recommended at meetings in November 1980, and 1982-83 programs were considered in September of the ARPAC Planning Group is that the ARPAC planning procedures have not proven satisfactory and there is a possibility that the Planning Group's activities will be drastically revised in 1982-83. The mechanics of planning have proved cumbersome and time-consuming, and co-ordinators have not been able to devote sufficient effort, for example, to encourage new workers to contribute to the research effort of the Australian National Antarctic Research Expeditions (ANARE).

ANTARCTIC WEATHER AND CLIMATE

A conference convened by the Australian Branch, Royal Meteorological Society was held at the School of Earth Sciences, Melbourne University in May, 1981. Truswell and Tingey were both invited to present papers: Truswell described palynological studies of Antarctic sedimentary rocks, and Tingey reviewed the terrestrial record of the development and fluctuation of the Antarctic ice cap. The available geological evidence appears to indicate that West Antarctica was glaciated before East Antarctica although glaciological considerations indicate that this was almost certainly not the case. The geological evidence consists of dated volcanic rocks that either overlie striated pavements or have characteristics that indicate subglacial eruption. However, isolated striated pavements are little more than indicators of local glaciation and not definite indicators of ice sheet glaciation; therefore, it seems that the onshore geological evidence is as yet inadequate to clearly delineate the development of Antarctica's glaciation.

Another aspect of Antarctic glacial history alluded to in Tingey's paper was the growing body of evidence that indicates Neogene uplift of the Transantarctic Mountains. This uplift appears to have been essentially coeval with the development of the Antarctic ice sheet and led to a damming back of the outlet glaciers that once flowed through the now 'dry' valleys west of McMurdo Sound. A possible cause of the uplift might be isostatic uplift in response to deep erosion along glacier channels - a mechanism discussed in detail by Wellman & Tingey in a paper on glaciation, erosion, and uplift in the Prince Charles Mountains area*. The Neogene uplift of the Transarctic Mountains may account for the development of the mountain range in its present form, and casts doubts on the importance of the mountains in the development of Antarctic glaciation - as postulated by some authors.

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* Nature, 291 (5811), 142-4.

BANDED IRON FORMATIONS IN EAST ANTARCTICA

Tingey was invited by Dr John Splettstoesser, editor of a forthcoming volume on the mineral resource potential of Antarctica, to contribute a chapter on the banded iron formations of East Antarctica. This formation is sparsely exposed and the few outcrops contain about 34% Fe; they would be subeconomic in most other continents and certainly in Australia. Given their location in remote and almost inaccessible parts of Antarctica their economic significance is minimal.

FIELDWORK IN DAVIS/PRYDZ BAY AREA by J.W. Sheraton

Sheraton spent 5 weeks mapping and collecting samples of high-grade metamorphics, and mafic and felsic igneous rocks for petrographic and geochemical study during the 1980/81 summer. Most time was devoted to examining Upper Proterozoic metamorphics of the Prydz Bay coast in order to more clearly define their relationships with the better-known upper Archaean gneisses of the Vestfold Hills. The work will also enable comparisons to be made with metamorphic rocks of both Archaean and Proterozoic age in MacRobertson, Kemp, and Enderby Lands.

Upper Proterozoic metamorphics of the Rauer Islands (charnockitic gneiss, garnet-biotite gneiss, mafic granulite) are compositionally similar to the Archaean rocks of the Vestfold Hills, a few kilometres to the north. Moreover, folded and metamorphosed relicts of the Vestfold Hills tholeiite dyke suite are present and provide evidence that the Rauer Islands rocks are the re-metamorphosed equivalents of the Vestfold Hills rocks. In contrast, upper Proterozoic metamorphics from the area to the southwest, as far as Landing Bluff, include abundant metasediments (garnet-cordierite-sillimanite gneisses, impure quartzites, etc.), whereas such aluminous rocks are rare in the Vestfold Hills. These may therefore represent a younger (?Proterozoic) series of sediments deposited on an Archaean basement like that of the Vestfold Hills. Charnockitic gneisses like those of the Rauer Islands and Vestfold Hills crop out at a few places, notably the eastern Munro Kerr Mountains. Porphyritic biotite-hornblende granite crops out around Sandfjord Bay and the Polarforschung Glacier; the Sandfjord Bay granite has given a Cambrian age.

YILGARN PROJECT

by

R.J. Tingey

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

INTRODUCTION

Work continued in conjunction with the Geological Survey of Western Australia (GSWA) on the 1:250 000-scale mapping of SANDSTONE and YOUANMI in the Yilgarn Block of Western Australia. Although fieldwork involved both BMR and GSWA staff, the tasks of map compilation and describing the work were allotted to the BMR participants; to date, Preliminary Editions of both map sheets are complete and a Record describing the YOUANMI work has been issued; that for the SANDSTONE work is still in preparation.

DISCUSSION

There is debate among Yilgarn workers about the nature of the relationship between the greenstone belts and other rocks, particularly the banded gneisses. In YOUANMI, Stewart & others (BMR Record 1981/23) suggest that rocks of the Cook Well greenstone belt unconformably overlie banded gneiss, and infer from the presence of an orthoquartzite unit at the base of the Maynard Hills greenstone belt that a sialic terrain was being eroded during deposition of the early greenstones. These notions match published theories of GSWA scientists who propose that banded gneisses, now best exposed along the western margin of the Yilgarn Block, formed a sialic basement upon which the lavas now seen as greenstone belts were erupted.

A different view of Yilgarn geology, supported by Dr A.Y. Glikson, postulates that there were at least two episodes of greenstone generation in the Yilgarn, and that the older one is now represented by greenstone and banded ironstone xenoliths within banded gneisses. This view assumes that granodioritic and tonalite magmas were generated by partial melting of greenstones and not by melting of the basement banded gneisses. The presence of very old greenstone sequences in the Pilbara region and the distribution of banded gneisses in the Yilgarn mainly at the margins of greenstone belts are cited as supporting evidence for the theory that greenstone sequences could have developed very early in the history of the Yilgarn Block.

The formation of banded gneisses from the tectonic intermingling of granite and greenstones has recently been reported from the Pilbara. Similar intermingling was mapped at one locality in SANDSTONE, where greenstone, intruded lit-par-lit by granitoid, grades laterally over about 20 m into banded gneiss. Elsewhere small enclaves of banded gneiss contain relict cores of banded iron formation and in some examples greenstone lavas. Experience in the SANDSTONE-YOUANMI area points to the possibility that in some places greenstones were deposited on banded gneissic sialic basement, whereas elsewhere banded gneisses were formed by tectonic and intrusive disruption of greenstone sequences.

GEOLOGICAL INVESTIGATIONS IN QUEENSLAND AND PAPUA NEW GUINEA

Supervising Geologists: G.M. Derrick (to March 1981), H.L. Davies (since April 1981).

MOUNT ISA-LAWN HILL PROJECT

by

I.H. Wilson (GSQ)

STAFF: BMR - G.M. Derrick (Project Leader until March 1981);
I.P. Sweet (overseas study leave), L.A.I. Wyborn (granites),
R.W. Page (geochronology), P.A. Scott (stream-sediment geochemistry until July 1981),
I.G. Hone (geophysics); J. Stirzaker,
J. Mifsud, G. Trott, G. Butterworth,
D. Green, P. Griffiths, H. Apps (draftsmen)
GSQ - I.H. Wilson, L.J. Hutton

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

The project is scheduled for completion in 1982.

RELATED INVESTIGATIONS: Geochronology, geochemistry, and granite studies (see Petrological, Geochemical and Geochronological Laboratories reports); geophysics of the Mount Isa region (see Geophysical Branch report); Duchess Project geology.

FIELD ACTIVITES

Limited field research was carried out in September 1981 during the preparation for the running of a three-day field excursion which was held in conjunction with the joint BMR/GSQ/AIMM Symposium on Mount Isa Geology. The excursion visited localities in KENNEDY GAP, MAMMOTH MINES, ALSACE, PROSPECTOR, MARY KATHLEEN, and MARRABA. An additional three days were spent in the field by Wilson, Hutton, and Bultitude (Duchess Project) who acted as guides for three geologists from the NSW Geological Survey in an examination of localities in CLONCURRY, MARRABA, MALBON, MOUNT ANGELAY, SELWYN, and DAJARRA.

The field excursion allowed an exchange of ideas between the 70 excursion participants, including members of the joint BMR/GSQ mapping projects. Several key localities were re-examined, including the Tommy Creek Microgranite age determination locality which was described in detail in last year's Geological Branch Annual Summary of Activities. The presence of felsic volcanic rocks in this sequence was confirmed by this visit. The development of skarn near Mary Kathleen and the relations between high-grade Leichhardt Metamorphics and the Kalkadoon Granite were among the other critical areas visited. The remaining excursion stops were mostly examples of topics discussed at the Symposium, and served to illustrate the stratigraphy and syndepositional tectonics in the McNamara Group and Surprise Creek and Quilalar Formations, the rock types in the Eastern Creek Volcanics and Myally Subgroup, and relations between Tewinga Group rocks in the Kalkadoon-Leichhardt block and the Wonga belt.

OFFICE ACTIVITIES

MAPS

First Edition 1:100 000: ALSACE is with the editors; MYALLY is in preparation.

Preliminary Edition 1:100 000: MYALLY, CARRARA RANGE REGION, CONSTANCE RANGE REGION, COOLULLAH, and MOUNT OXIDE REGION were issued; and MAMMOTH MINES is at an advanced stage of preparation.

Second Edition 1:250 000: CLONCURRY has been compiled, LAWN HILL is in preparation.

REPORTING OF RESULTS

A BMR Record was issued for CARRARA RANGE REGION (1980/76). GSQ Record 1980/34 by Wilson & Hutton, which describes geological fieldwork carried out during August and September 1980, was also issued.

Map Commentaries were published for SEIGAL and HEDLEYS CREEK, edited for LAWN HILL REGION, and are in preparation for MOUNT OXIDE, ALSACE, and MYALLY. Microfiche Reports were published for stratigraphic nomenclature (BMR Report 225) and chemical analyses (BMR Report 226) in SEIGAL and HEDLEYS CREEK. A paper in the Queensland Government Mining Journal by Hutton & others describes new and revised stratigraphic units in the Lawn Hill Platform.

A book entitled 'Precambrian of the South Hemisphere' (D.R. Hunter, Editor), which contains a chapter by Plumb & others describing the Proterozoic of northern Australia, was published by Elsevier. A discussion by Derrick & Wilson of a paper by Holcombe & Fraser was published in the Journal of the Geological Society of Australia, and a discussion by Derrick & Wilson of a paper by Blake was published in the BMR Journal.

Four lectures were presented by members of this project at the Symposium on Mount Isa Geology. Derrick set the geological framework with a paper entitled 'Mount Isa Inlier - stratigraphic outline and geological history'. Hutton & Sweet described 'Geological evolution, tectonic style and economic potential of the Lawn Hill Platform cover, northwest Queensland'. Wilson evaluated statistical techniques in 'Discriminating between acid volcanic units in the Mount Isa region'. The 'Eastern Creek Volcanics - their geochemistry and possible role in copper mineralisation at Mount Isa' was presented by Wilson & Derrick. Papers on geochronology, geophysics, and granites were presented by Page, Hone, and Wyborn. An excursion guide for this meeting was prepared by Derrick, Wilson & Hutton.

Wilson completed an examination of thin sections from north of 20°S latitude and added relevant parts of this information to a catalogue of volcanic rock descriptions from the northern part of the Mount Isa Inlier. Some of these data and geochemical data have been computerised by Wilson.

MISCELLANEOUS

Sweet is currently completing a course in Advanced Sedimentology conducted by Dr J.R.L. Allen at Reading University.

Derrick resigned from the BMR in March 1981, and Scott resigned from the BMR in July 1981. Derrick, Wyborn, Page, Hone, Wilson and Hutton attended the joint BMR/GSQ/AIMM Symposium on Mount Isa Geology 15 and 16 September 1981.

DUCHESS PROJECT

by

D.H. Blake

STAFF: D.H. Blake (Project Leader); R.J. Bultitude (resigned 15 May 1981, now GSQ); P.J.T. Donchak (GSQ).

AIMS: To review the stratigraphy, structure, geological history, and mineral potential of the Precambrian parts of DUCHESS and URANDANGI, and to correlate the Precambrian rocks with those mapped by G.M. Derrick and co-workers in CLONCURRY and MOUNT ISA to the north.

SIGNIFICANCE: The area investigated covers the southern part of the Mount Isa Inlier, an important metallogenic province containing numerous economic and potentially economic deposits of Cu, Au, Ag, Pb, Zn, Co, and U.

RELATED INVESTIGATIONS: U-Pb zircon geochronology by R.W. Page, geochemical/ petrological studies by L.A.I. Wyborn on igneous rocks in the area, and petrological study by A.L. Jaques of the regional metamorphism in the eastern part of DUCHESS (see Geochronological and Petrological Laboratories reports); assessment of the regional geophysics, using available gravity and aeromagnetic data together with rock physical property data, by I.G. Hone (see Geophysical Branch Annual Summary of Activities 1981).

STATUS OF PROJECT

The Duchess Project is due to be completed by the end of 1981. Field work commenced in 1975 and was completed in 1980. By October 1980 the 1:100 000 scale Preliminary Edition maps covering the area had been issued, and comprehensive reports describing the geology of each map area had been released as BMR and GSQ Records. The 12-month period to October 1981 was spent preparing maps, reports, and papers for publication.

MAPS

First Edition 1:100 000 scale: DAJARRA and DUCHESS REGION (Special) are in press; ARDMORE has been edited and is being fair drawn; SELWYN REGION (Special) and KURIDALA REGION (Special) are being edited.

Preliminary Edition 1:250 000 scale: DUCHESS SPECIAL (DUCHESS and eastern third of URANDANGI) was issued in March 1981.

First Edition 1:250 000 scale: GEOLOGY OF THE DUCHESS-URANDANGI REGION (Special) has been edited and is being prepared for fair drawing.

REPORTS

Map Commentaries to accompany DAJARRA, DUCHESS REGION, and ARDMORE are with the editors; those to accompany SELWYN REGION and KURIDALA REGION have been prepared and will be finalised when editing of the maps has been completed. Newly named and revised stratigraphic and intrusive units are defined in a microfiche report (BMR Report 233). A Bulletin synthesising the Precambrian geology of the Duchess-Urandangi region, to be accompanied by the 1:250 000 scale map, is in preparation and should be completed and ready for editing by Christmas 1981.

PAPERS

1, on intrusive felsic-mafic net-veined complexes, by Blake (BMR Journal, 6 (1)): the mafic component of such complexes is either contemporaneous with or younger than the felsic component.

2, on an alternative interpretation for the early geological history of the Mount Isa Inlier, a reply by Blake to a discussion by Derrick & Wilson (BMR Journal, 6 (3)): further evidence is presented to support the suggestion that much of the Haslingden Group of the 'Western Succession' is older than the Argylla Formation of the 'basement', and that rocks mapped as Corella Formation may range in age from pre-Haslingden Group to post-Mount Isa Group.

3, on a summary of new and revised stratigraphic nomenclature in <u>DUCHESS</u> and <u>URANDANGI</u>, by Blake, Bultitude, & Donchak (accepted for publication in Queensland Government Mining Journal).

4, on intrusive breccias near Duchess, by Blake, Bultitude, & Donchak (submitted for publication in BMR Journal): rocks previously mapped as Mount Philp Agglomerate are intrusive breccias emplaced after the surrounding Corella Formation and had been deformed and metamorphosed.

5, on a review of the Corella Formation, by Blake (in preparation): it is suggested that the rocks previously mapped as Corella Formation should be re-assigned to several separate new formations.

6, on volcanic rocks in the Duchess-Urandangi region, by Bultitude & Wyborn (in preparation): regionally metamorphosed felsic and mafic volcanic rocks are present in many of the Proterozoic formations; a general absence of volcanic rocks of intermediate composition may indicate an extensional crustal regime, rather than a volcanic arc environment, during much of the Proterozoic. (Papers 5 and 6 were presented orally at the Mount Isa Symposium 15 and 16 September 1981).

7, on regional metamorphism in the eastern part of DUCHESS, by Jaques, Blake, & Donchak (in preparation): upper greenschist, lower to middle amphibolite, and upper amphibolite grade zones have been recognised; the metamorphism is of low pressure-high temperature type.

D.H. Blake and R.J. Bultitude attended the joint BMR/GSQ/AIMM Mount Isa Symposium, 15 and 16 September 1981.

GEORGETOWN PROJECT

by

B.S. Oversby, I.W. Withnall, D.E. Mackenzie, and J.V. Warnick.

STAFF: Full-time - B.S. Oversby (Co-ordinator), D.E. Mackenzie[1]; I.W. Withnall[1] and J.V. Warnick[1] (GSQ).

Part-time - K.J. Armstrong[2], L.P. Black[3], P.J. Corbett[4], D.J. Gregg[5], F.Guy[3], J.A. Haldane[2], G.A.M. Henderson[1], C.L. Johnson[4], C.P. Knight[4], P. Moffat[4], J.G. Pyke[2], A.J. Retter[4], P.A. Scott[2] (resigned 26 June).

([1] geology [2] geochemistry, [3] geochronology, [4] drafting, [5] field camp management).

AIMS:

The Project aims to substantially enhance and integrate geological, geochemical, and geophysical knowledge of mainly Proterozoic to Palaeozoic rocks in the Georgetown region, northeastern Queensland, as an aid to mineral exploration, and as a step towards understanding northeastern Australia's evolution.

PROGRESS

Synthesis of results from completed work in the central and western parts of the Georgetown region continued during the first half of the year. The area covered was mainly GEORGETOWN, FORSAYTH, GILBERTON, FOREST HOME, NORTH HEAD, GILBERT RIVER, ESMERALDA, and CROYDON; results will be presented as a special 1:250 000-scale geological map in full colour, with supporting geochemical and other diagrams, and text. Concurrently, the relevant limited-colour 1:100 000-scale Preliminary Edition Geological Series maps were progressively updated. This aspect of the project was temporarily suspended during the second half of the year in favour of more pressing commitments, but will continue during 1982. An associated activity was the computerisation of rationalised stream-sediment geochemical data, permitting automatic plotting of summary maps showing locations of samples with values of selected elements of interest equal to or greater than threshold, and one standard deviation above threshold.

Some results of field research in NORTH HEAD and FOREST HOME have been compiled as a data Record dealing with the Proterozoic metasedimentary sequence and entitled 'Proterozoic stratigraphy, metamorphism, and structure of the North Head-Forest Home area, north Queensland', which is currently being edited. A related Record, describing Proterozoic and Palaeozoic igneous rocks, and the Mesozoic-Cainozoic sequence, in the same areas, is being prepared. Geological data from GILBERT RIVER and adjacent parts of STRATHMORE have been combined in a 1:100 000-scale Preliminary Edition Geological Series Special map entitled 'Gilbert River Region', which is with the printers. Field scale (approximately 1:25 000) compilation sheets of this area have been released, and a Record (1981/52) cataloguing them is in press. Preparation of additional Preliminary Edition special maps at 1:100 000 scale, illustrating geology in the ESMERALDA REGION (ESMERALDA and parts of PROSPECT and PELHAM), and in the CROYDON REGION (CROYDON with parts of WALLABADAH), is under way: all field compilation sheets of these areas are ready for release.

Stream-sediment geochemistry maps, also at 1:100 000 scale, of GEORGETOWN and GILBERTON, were finalised and released during the year. Both Sheet areas are covered by four maps, each of which shows values for three elements in combinations which appear to be of the most direct local relevance.

The final major phase of geological field research in the southeastern Georgetown region (mainly parts of LYNDHURST, EINASLEIGH, CONJUBOY, and BURGES) was undertaken between June and mid-September by Oversby, Withnall, and Warnick. In addition, during August, Black and Guy collected a large number of samples from throughout the Georgetown region for isotopic age determination, mostly by the zircon (U-Pb) technique. Mackenzie visited the Georgetown-Croydon area, also during August, in order to select material to be sampled by Black and Guy, and to finalise various aspects of previous fieldwork. He also reconnoitred the Chillagoe-Dimbulah area preparatory to the start of field-based research there in 1982.

There was no geophysical input to the Project during the year.

FIELD ACTIVITIES

Oversby and Withnall studied the nature and tectonic significance of Proterozoic to lower Palaeozoic metasedimentary and associated rocks, and their structures and mineral deposits, in the southeastern part of the Georgetown region. Oversby was mainly responsible for the Einasleigh Metamorphics, while Withnall examined the Balcooma metamorphics*, Lucky Creek and Paddys Creek Formations, and adjacent units farther east. Warnick made a semi-independent investigation, mainly of the Einasleigh Metamorphics, Oak River Granodiorite, and upper Palaeozoic rocks in south-central and southwestern EINASLEIGH; he aims to clarify relationships between them and the Kidston breccia pipe.

Black and Guy sampled the White Springs Granodiorite, Forsayth Granite, Lighthouse Granite, Dido Granodiorite, Robin Hood Granite, Mistletoe Granite, Dumbano Granite, Forest Home Granodiorite, and Esmeralda Granite from localities in the western, central, and southeastern Georgetown region for U-Pb dating of contained zircons; most of the rocks have yielded ambiguous results by other methods. The Awring granodiorite* and Wallys dolerite* were also sampled in the western part of the region: they will be dated by means of K-Ar or Rb-Sr, or both, at least initially. Sampling of thes[illegible]as under Mackenzie's guidance, and, in addition, he located a suitable sample of Esmeralda Granite for dating, and revisited critical localities around Mount Little and Pleasant Creek (GILBERT RIVER) in order to clarify the results of field research there in 1980. Relationships of Goat Creek and McFarlanes basalts* to other rocks are still unclear; however, it is thought most likely that they constitute part of the Croydon Volcanics (Croydon volcanic group*). Copper mineralisation at Mount Little is now known to occur in Awring granodiorite, a fine-grained marginal phase which was recognised locally.

LYNDHURST AND ADJACENT 1:100 000 SHEET AREAS

Einasleigh Metamorphics (Figs. M7 and M8).

Five main subunits are now recognised in the multiply-deformed and metamorphosed Einasleigh Metamorphics of LYNDHURST, southern EINASLEIGH, and southwestern CONJUBOY-northwestern BURGES. The most extensive of these is characterised by mostly moderately to well-banded, mesocratic, calc-silicate (hornblende and/or diopside)-rich quartzofeldspathic gneisses which commonly contain garnet and magnetite; amphibolites are relatively rare. This subunit may be amenable to further subdivision, although no marker intervals as such have been recognised. A second subunit consists mainly of locally migmatitic,

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* Stratigraphic names presented thus are informal; all are reserved with the Central Register of Australian Stratigraphic Names.

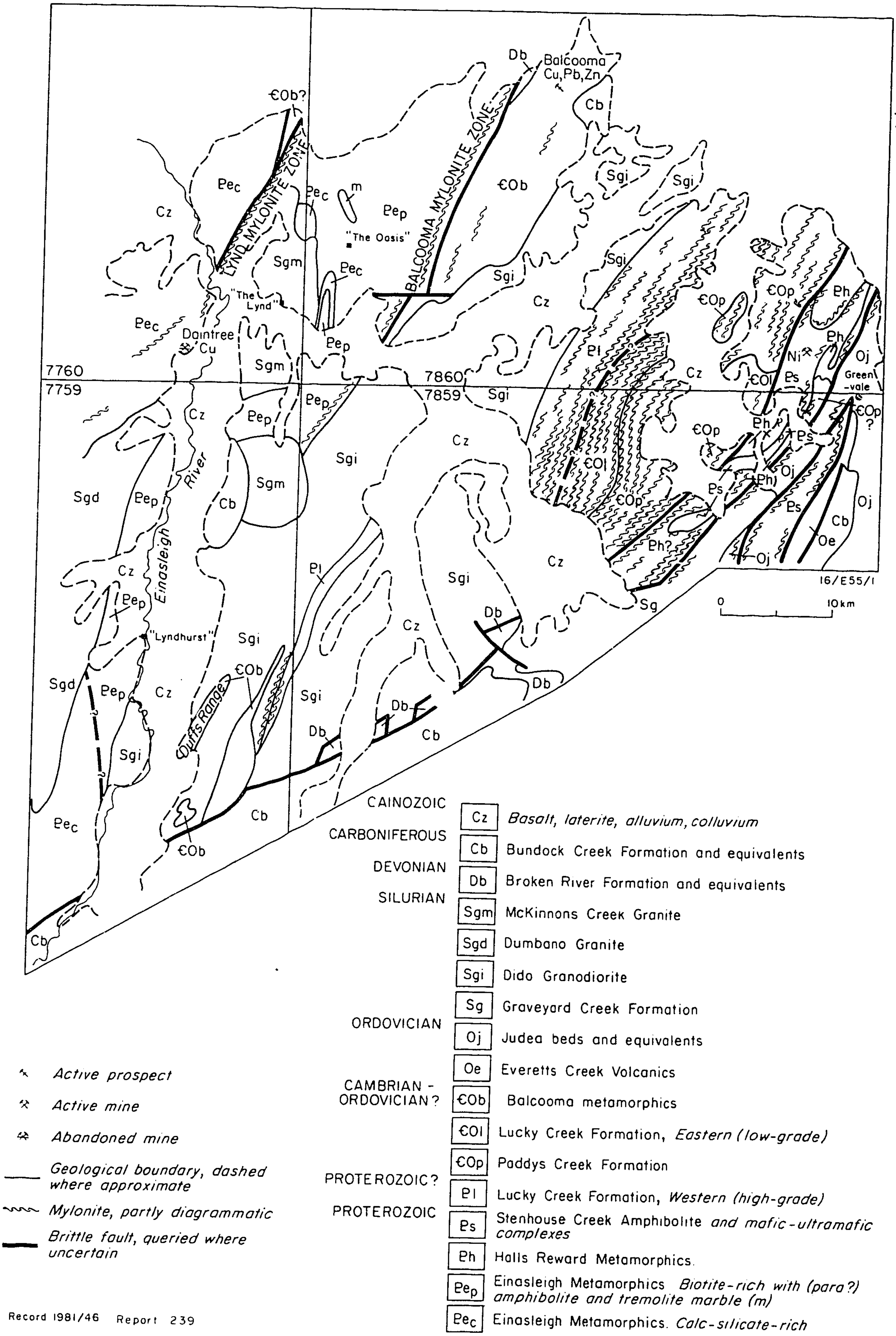

Fig M7 Simplified geological map of the Lyndhurst - Greenvale area, embracing parts of the Lyndhurst (7759), Einasleigh (7760), Conjuboy (7860), and Burges (7859) 1:100 000 Sheet areas.

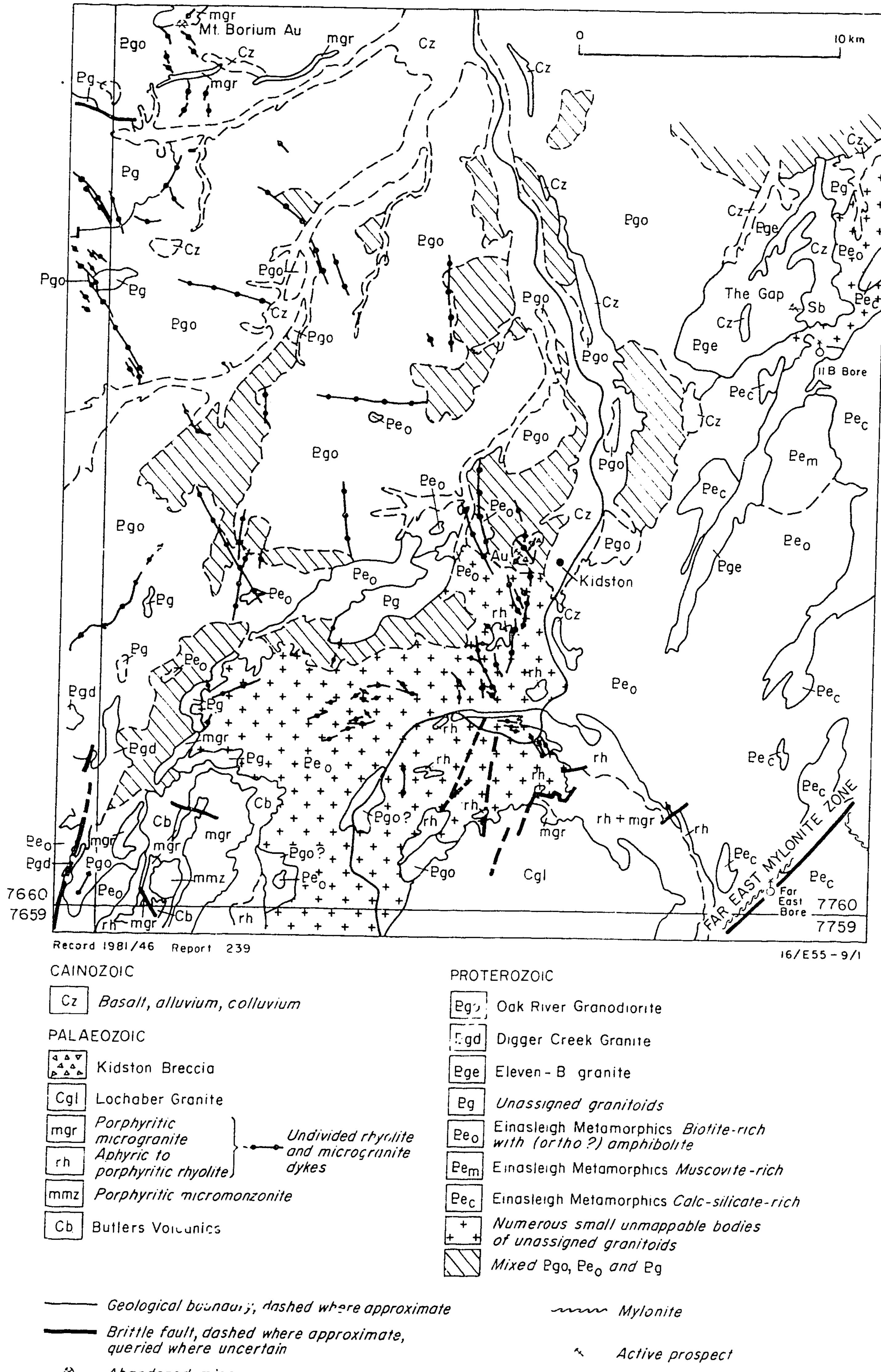

Fig M8 Simplified geological map of the south-central and southwestern Einasleigh 1:100 000 Sheet area, with immediately adjacent parts of the Forsayth (7660), Gilberton (7659), and Lyndhurst (7759) Sheet areas mesocratic to melanocratic, biotite-rich quartzofeldspathic schist and gneiss with sporadic lensoidal bodies of mostly massive (ortho)amphibolite. The subunit is poorly developed in LYNDHURST, but it becomes increasingly important farther north, to the point where it is apparently the dominant subunit in central to northern EINASLEIGH, and in MOUNT SURPRISE. Subunit (3) contains leucocratic quartzofeldspathic granofels and gneiss with little or no calc-silicate and biotite content, but commonly contains garnet and magnetite; it occurs discontinuously between the subunits (1) and (2). Most known magmatogenic-exhalative-type barite and base-metal sulphide occurrences in the Einasleigh Metamorphics appear to be spatially associated with some degree of development of this subunit (Oversby, 1981*), which may represent original felsic tuffs and lavas. Mesocratic, locally migmatitic, muscovite-rich quartzofeldspathic schist and gneiss constitute a fourth subunit, of very restricted occurrence in southern EINASLEIGH (Fig. M8). Einasleigh Metamorphics in a structural block centred on The Oasis (southwestern CONJUBOY) consist of biotite-rich quartzofeldspathic schist with thin interlayers of well-foliated, commonly laminated (para?)amphibolite, and lenses of white tremolite marble, making up subunit (5). Concordant calc-silicate-rich gneisses, like those typical of subunit (1), occur locally in the block near ND Creek and on Mount Esk.

Contacts between all five subunits are gradational in detail, and the subunits probably intertongue both laterally and vertically. No unambiguous younging data have been found; however, information from elsewhere in the region (mainly in GEORGETOWN and GILBERTON) strongly suggests that the calc-silicate-rich subunit is laterally equivalent to lower-grade Bernecker Creek Formation, while biotite and muscovite-dominated rocks associated with amphibolites represent sedimentary and metamorphic facies variants of the overlying Robertson River Formation. Both of these lower-grade units are believed to have accumulated in shallow water (see Geological Branch Annual Summary of Activities for 1979 - BMR Report 222). The leucocratic quartzofeldspathic granofels-gneiss subunit (3) has no obvious low-grade counterpart.

The Einasleigh Metamorphics of the study area appear to have been affected by four or more major episodes of folding, and to have been metamorphosed at least once (probably twice) under amphibolite grade conditions.

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* Fifth Australian Geological Convention, Perth, August 1981, Abstracts, 3, 13.

Possum Pad granite*

Small to medium-sized, sharply-defined, bodies of a distinctive foliated, leucocratic to mesocratic white megacrystic biotite granite cut calc-silicate-rich Einasleigh Metamorphics in a relatively small area on both sides of the Einasleigh River about 12 km west of The Oasis (southeastern EINASLEIGH). This granite, of probable Proterozoic age, is one not previously encountered: it is accordingly provisionally named from the track (formerly main road) between The Lynd and the present Einasleigh road.

Oak River Granodiorite

Proterozoic Oak River Granodiorite, the main constituent of the Copperfield Batholith, crops out in southwestern EINASLEIGH and southeastern FORSAYTH, to the north and west of Kidston (Fig. M8). The characteristic rock type in most of the area is a grey medium-grained, locally foliated, variably megacrystic biotite granodiorite. Megacrysts are subhedral to euhedral pink potash feldspar laths up to 6 cm long, commonly containing concentric zones of included biotite flakes. In the eastern part of the outcrop area, megacrystic granodiorite grades locally into a slightly darker grey, mostly foliated, medium-grained equigranular hornblende-biotite granodiorite or tonalite, with scattered mafic clots 2-3 cm across.

Trondhjemite? in two bodies between the Butlers Volcanics and edge of the Lochaber Granite in southwestern EINASLEIGH is assigned to the Oak River Granodiorite (Fig. M8).

Eleven-B granite*

Two moderately large, sharply defined bodies of poorly to moderately foliated white to pink leucocratic medium-grained equigranular muscovite grading to biotite granite (the latter predominant) occur on the eastern edge of the Copperfield Batholith, north and south of 11B Bore (Fig. M8), from which it is provisionally named.

Unassigned granitoids

Einasleigh Metamorphics and Oak River Granodiorite in LYNDHURST and southern EINASLEIGH contain abundant, mostly small, concordant and discordant (with respect to metamorphic banding or foliation) bodies of unfoliated to well-foliated leucocratic granitoid and pegmatoid. Such bodies are most widespread in biotite and muscovite-rich Einasleigh Metamorphics subunits, although they are also common locally in others; mica and calc-silicate contents are

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* informal name

typically low. Some of the muscovite-bearing varieties contain garnet, and are of Digger Creek-type; however, Digger Creek Granite sensu stricto (i.e. continuous with that in the type area) occurs only in the extreme southwesternmost corner of EINASLEIGH. Others of the leucogranitoids are of Eleven-B-type (above).

The unassigned leucogranitoids and leucopegmatoids are probably anatectic and, occur at or near their original sites of formation. Several generations are evidently represented, implying either an extended period under appropriate metamorphic conditions, or recurrent melting events during separate metamorphic events or both.

Balcooma metamorphics*

The Balcooma metamorphics, previously (Geological Branch Annual Summary of Activities for 1980 - BMR Report 230) described from the main area of preservation in the western half of CONJUBOY (Fig. M7), consist of a well-foliated lower amphibolite facies sequence of volcanic and sedimentary rocks associated with bodies of apparently cogenetic biotite microgranite to granite. The sequence dips east, and is overturned.

Leucocratic, locally migmatitic, muscovite and biotite-rich schist, gneiss, and granofels in large (several kilometres long) screens or roof pendants in Dido Granodiorite of the Duffs Range area, east-central LYNDHURST (Fig. M7), previously tentatively assigned to the Einasleigh Metamorphics, are now believed to belong to this unit. Muscovite gneiss locally contains quartz 'eyes' and apparent relict lapilli, suggesting a volcanic origin; relatively massive biotite leucogneiss and granofels are probable equivalents of the foliated microgranite-granite in the Balcooma area.

A structural slice, up to one kilometre wide, of carbonaceous phyllite, schist, and meta-arenite, occurs about 12 km northwest of The Oasis (Fig. M7). These rocks are similar to others occurring locally in the Balcooma metamorphics of the Balcooma area, and are tentatively correlated with them.

The Balcooma metamorphics are probably of early Palaeozoic age.

Lucky Creek Formation

As originally defined and mapped (White, 1965, BMR Bulletin 71, pp. 30-31), the Lucky Creek Formation crops out mainly in southeastern CONJUBOY (Fig. M7). It contains a variety of rock types, and was considered to be entirely of Proterozoic age. The outcrop area of the unit is separated from the main Balcooma metamorphics by a belt of Dido Granodiorite.

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* informal name

The western part of the Lucky Creek Formation, as originally delineated, consists of a sequence of amphibolite facies biotite-rich quartzofeldspathic gneiss, and leucocratic quartzofeldspathic gneiss, with amphibolite, 'dioritic gneiss', and sporadic marble. Amphibolites are of two types: the first as layers a few centimetres thick within biotite gneiss; the second as thicker, more massive bodies which contain possible relict pillows and agglomeratic texture. Amphibolites of the first type are strikingly similar to those in rocks assigned to Einasleigh Metamorphics around The Oasis (above), and on this basis the western Lucky Creek Formation is tentatively considered to be of similar (probably mid-Proterozoic) age. The 'dioritic gneiss' of earlier workers crops out in a belt several kilometres wide, and more than 10 km long. It is a well-foliated, medium-grained hornblende-biotite rock which contains sporadic 'amphibolite' bands (although characteristically unbanded). Some of these bands show intersecting relationships, suggestive more of cross-cutting veins than of transposed stratification; this feature, combined with the rock's overall grainsize, suggests an intrusive origin.

Farther east, the Lucky Creek Formation contains lower-grade chlorite and/or actinolite schist with relict feldspar phenocrysts and local lapilli, evidently representing intermediate volcanic rocks. More felsic metavolcanic or dyke rocks, or both, also occur, but are a relatively minor component of the unit. These rocks are similar to those constituting the Ordovician Everetts Creek Volcanics (White, 1965, BMR Bulletin 71, p.44) of the Broken River Province.

Thus, the Lucky Creek Formation as currently defined appears to be a composite unit. Relationships between the western (high grade) and eastern (low grade) parts are uncertain because of a pervasive mylonitic foliation (below). The mylonitic foliation probably represents a structural discontinuity between Proterozoic and Palaeozoic sequences, or, alternatively, may coincide with a change in metamorphic grade within a single continuous sequence of one age.

Paddys Creek Formation

This unit (White, 1965, BMR Bulletin 71, p. 31) crops out to the southeast of the Lucky Creek Formation, in southeastern CONJUBOY and northeastern BURGES (Fig. M7). It contains phyllite and fine-grained muscovite schist; some of the rocks appear to be feldspathic, and may contain a fine tuffaceous component. Relatively large crystal and lithic fragments occur only near the contact with intermediate volcanic rocks in the eastern (low-grade) Lucky Creek Formation, suggesting a gradational or intertonguing contact between the two, and implying a shared, possibly early Palaeozoic age.

Halls Reward Metamorphics

In the Greenvale area (southeasternmost CONJUBOY and northeastern BURGES), the Halls Reward Metamorphics (White, 1965, BMR Bulletin 71, pp.25-28) consist of coarse muscovite-rich quartzofeldspathic schist with pegmatoid veins. The rocks are spatially intimately associated with Stenhouse Creek Amphibolite, and probably related mafic to ultramafic rocks of the Proterozoic (Arnold & Rubenach, 1976)[1] Boiler Gully and Sandalwood Complexes. Contacts with the Paddys Creek Formation to the west, and Judea beds (Arnold & Henderson, 1976)[2] to the east, appear to be structural. The Halls Reward Metamorphic and mafic-ultramafic rocks may all represent a structurally bounded association of Proterozoic age.

Mylonite zones

Although mylonite zones of probable early Palaeozoic age have been recognised only relatively recently in the Georgetown and adjacent (Broken River and Hodgkinson) provinces (Withnall, Bain, & Rubenach, 1980[3]; Bell, 1980[4]), it is now obvious that they have some major, albeit as yet obscure, significance in relation to the tectonic evolution of, and interplay between, those provinces. In addition, many of the mylonite zones have been followed by younger brittle faults and intrusive bodies: they were probably at least partly instrumental in channelling and localising late Palaeozoic magma at high crustal levels, and in the related development of volcanic-related structures in the Newcastle Range-Featherbed Field (Oversby, Black, & Sheraton, 1980)[5].

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1. Arnold, G.O., & Rubenach, M.J., 1976: Mafic-ultramafic complexes of the Greenvale area, north Queensland: Devonian intrusions or Precambrian metamorphics? Journal of the Geological Society of Australia 23, 119-139.

2. Arnold, G.O., & Henderson, R.A., 1976: Lower Palaeozoic history of southwestern Broken River Province, north Queensland. Journal of the Geological Society of Australia 23, 73-93.

3,4,5 Refer to papers in Henderson, R.A., & Stephenson, P.J. (eds.): The Geology and geophysics of northeastern Australia. Geological Society of Australia, Queensland Division, Brisbane - (3) pp. 109-127, (4) pp. 307-313, (5) pp. 247-268.

The approximately vertical, one-to-two-kilometre-wide, Balcooma Mylonite Zone (Fig. M7), one of the first to be recognised, strikes north-northeast and contains steeply plunging lineations on its foliation surfaces. It separates Balcooma metamorphics in their main area of development from rocks assigned to Einasleigh Metamorphics around The Oasis (above); it also forms the boundary between the Forsayth and Greenvale Subprovinces of the Georgetown Province (Withnall & others, 1980)*. The correlation of rocks in the Duffs Range area with Balcooma metamorphics (above) reinforces a previous suggestion (Geological Branch Annual Summary of Activities for 1980) that the southern extension of the zone lies beneath Cainozoic basalt and younger cover in the Einasleigh River valley, at least as far as the trace of the Burdekin River Fault Zone. Penetrative non-mylonitic foliation in the Balcooma metamorphics is parallel to the mylonitic foliation, and the two are probably related: the Balcooma sequence may not lie on a fold limb, as was thought originally (Geological Branch Annual Summary of Activities for 1980). Mylonitisation in the Balcooma Mylonite Zone apparently took place at about the same time as prograde amphibolite facies metamorphism.

The block of Einasleigh Metamorphics centred on The Oasis is bounded westwards by the steep, north-northeast-striking Lynd Mylonite Zone (Fig. M7), which is about one kilometre wide. Lineations and fold axes within the zone plunge steeply. Einasleigh Metamorphics west of the zone belong to the calc-silicate-rich subunit. A main southward extension of the Lynd Mylonite Zone apparently lies along the western edge of the Einasleigh River valley, mostly obscured by cover and Dumbano Granite. The zone may also in part branch westwards and southwestwards into the series of smaller, retrogressed zones which cut calc-silicate-rich Einasleigh Metamorphics between Daintree mine (Fig. M7) and Far East Bore (Fig. M8), in southern EINASLEIGH. However, these smaller zones are discontinuous and anastomosing, and appear to have been folded; they may be not directly related to any of the major linear zones.

Farther west again, Einasleigh Metamorphics are cut by the mostly poorly exposed, steeply dipping Far East Mylonite Zone. This strikes northeast from the Lochaber centred igneous structure, through the Far East Bore area (Fig. M8), into the Einasleigh River valley between The Oasis and Carpentaria Downs. The zone was probably originally connected directly, or indirectly via a series of subsidiary zones, to the Werrington and/or Gilberton Faults, farther to the south and southeast, both of which coincide, at least in part, with older mylonite zones.

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* See footnote 3 on the previous page.

Dumbano Granite and Dido Granodiorite have been mylonitised locally. In addition, both units, and the McKinnins Creek Granite, commonly contain a penetrative non-mylonitic foliation parallel and probably related to, the mylonitic foliation, suggesting that they were emplaced at the present level of exposure at about the time that mylonitisation took place.

East of the main area of Balcooma metamorphics, the relatively well-defined mylonite zones are replaced by more diffuse belts of pervasive mylonitic and intense non-mylonitic foliation (Fig. M7) where any pre-mylonite structures which might bear on the age of the rocks have been obscured, and the location and nature of boundaries within and between units are rarely clear. These factors particularly hinder understanding of the Lucky Creek and associated formations in southeastern CONJUBOY.

Formation of the mylonitic and associated foliations in the area is believed to have accompanied one or more periods of major thrusting - an interpretation made independently by Bell and colleagues of James Cook University (personal communications, 1980, 1981). The geometries, spatial and temporal inter-relationships, and total translation histories of various thrust sheets are still obscure, as is the tectonic significance of the postulated thrusting (which evidently involved both basement and cover sequences). Thrusting-mylonitisation, intrusion of mafic-ultramafic bodies and complexes, prograde metamorphism-granitoid emplacement, and early subsidence in the Hodgkinson and Broken River belts, may have been related to a Late Proterozoic and early Palaeozoic episode of intrasialic plate rifting, succeeded by closure, centred at a triple junction of which the Broken River embayment represents one arm (isolated by later rifting and opening of the Tasman Sea). In this scenario, the postulated thrusting would have accompanied closure of the rifts, and would have been towards the west or northwest in the area under consideration; the model implies the possible existence of major mylonites reflecting eastward or southeastward thrusting in the Lolworth-Ravenswood block. The mylonites now seen in LYNDHURST and adjacent 1:100 000 Sheet areas may be related to a regional detachment below calc-silicate-rich Einasleigh Metamorphics in unexposed (partly Archaean?) basement.

The precise timing of mylonitisation and postulated thrusting is still not fully resolved. Clasts of mylonitised rhyolite and ultramafic rocks in the Crooked Creek Conglomerate Member (lowermost Graveyard Creek Formation) indicate that the activity took place, at least locally, before or during Silurian time. However, data from the Balcooma metamorphics suggest an early Devonian timing

(T.H. Bell and L.P. Black, personal communication 1981). These data are not necessarily in conflict - there might have been more than one period of mylonite formation, or a regional continuum of mylonitisation spanning a relatively long period of time. Major deformation and metamorphism in the Balcooma area were certainly completed by about mid-Devonian time, when arkosic sandstones and fossiliferous limestones were deposited unconformably on Balcooma metamorphics. Mylonitic foliation in the Lucky Creek Formation and other eastern units has been deformed by large tight upright folds (overprinted by at least two generations of later, more open folds) which are believed to have formed at the same time as slaty cleavage-related structures in Hodgkinson and Broken River Province rocks - at 380-385 m.y., Late Devonian (Bell, 1980)[1]. The discrete mylonite zones in the western part of the area may owe their uniformly steep dips entirely to this and succeeding deformations, or they may originally have ramped at the crustal level now exposed.

Upper Palaeozoic dykes and Kidston breccia pipe

A northwest-striking belt of steeply dipping upper Palaeozoic dykes and minor irregular stocks occurs in western EINASLEIGH, between the northern end of the Lochaber pluton and Butlers Volcanics (Fig. M8) and the southeastern Newcastle Range. This belt of intrusions, and a gravity trough which is coincident with it, both suggest that the Bagstowe-Lochaber and Newcastle Range structures (Oversby & others, 1980)[2] are connected by a more-or-less continuous granitic batholith at relatively shallow depth.

Dyke trends in the belt are individually and collectively very variable, although predominantly north to northwest. The rock types range from cream, buff, grey, or greenish-grey, and brown to red, aphyric through variably porphyritic rhyolites to porphyritic microgranites; porphyritic rhyolites and microgranites are most common. Rhyolites are locally flow-banded and brecciated, and some are pyritic. There appear to be no consistent cross-cutting relationships between dykes of different trends, or of different lithologies, nor is any particular lithology restricted in trend. Evidently, intrusion was unsystematic and recurrent.

The same rock types occur as a series of sheets which dip inwards at a shallow angle (about 25°) around the eastern and northern margins of the Lochaber Granite (Geological Branch Annual Summary of Activities for 1980).

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1 - see footnote 4 on page 109.

2 - see footnote 5 on page 109.

Relationships between these sheets and the dykes are uncertain, but it is possible that the former gradually steepen as they diverge from the northern end of the granite pluton.

The gold and base-metal-mineralised Kidston breccia pipe occurs in an area of especially abundant dykes, on the eastern edge of the belt(Fig. M8); it cuts a mixed terrain of Einasleigh Metamorphics, Oak River Granodiorite, and unassigned granitoids at the southeastern corner of the Copperfield Batholith, and has been intruded by north and northwest-striking aphyric and porphyritic rhyolite dykes. Intensely altered (mainly sericitised) fragments from all of the transected units occur in the breccia of the pipe, together with clasts of rhyolite.

The Kidston breccia pipe and its mineralisation are the products of locally intense and channelled hydrothermal activity in a zone of relatively close fracturing above the eastern edge of a buried granite ridge. However, more specific factors controlling its localisation are not evident at the present level of exposure. The nearby Lochaber structure was emplaced into an area of crustal weakness at the intersection of the major Gilberton and Werrington Faults, and the Far East Mylonite Zone; however, the northwest-striking dyke belt and the buried granite ridge apparently had some independent major (deep crustal?) control.

Precise ages of brecciation and mineralisation at Kidston are not yet known; likewise, the component parts of the Lochaber centred igneous structure remain to be dated. Intrusive rocks similar to those of the dyke belt are all about 330 m.y. old, mid-Carboniferous, in the Newcastle Range area (Oversby & others, 1980).

Gold at Mount Borium, about 25 km northwest of Kidston (Fig. M8), and stibnite at The Gap prospect, about 17 km north-northeast of Kidston (Fig. M8), both occur in brecciated rhyolite; the latter occurrence is outside the main dyke belt.

OFFICE ACTIVITES

CROYDON AND ADJACENT 1:100 000 SHEET AREAS

Continued revision and rationalisation of geology in CROYDON and adjacent 1:100 000 Sheet areas have resulted in some changes being made to the preliminary stratigraphic nomenclature presented previously (Geological Branch Annual Summary of Activities for 1980), as outlined below.

Croydon volcanic group

This group is now considered to consist of (in ascending stratigraphic order): unnamed sedimentary rocks of local occurrence; Goat Creek basalt and McFarlanes basalt (probably laterally equivalent); Wonnemarra rhyolite; B Creek rhyolite (previously B Creek dacite); Parrot Camp rhyolite; Carron rhyolite; and Idalia rhyolite, containing the Democrat (Rhyolite) member (all informally named). Most of the previous Pleasant Creek andesite has been included in B Creek rhyolite (which includes minor dacitic and andesitic components), and not given a separate name; other rocks originally assigned to the unit are now recognised as belonging to a fine-grained melanocratic variant of Olsens granite (below). Thus, use of 'Pleasant Creek' is discontinued.

Esmeralda Granite and related rocks

The name Esmeralda Granite is now restricted to the coarse-grained biotite granite constituting the largest exposed pluton in the western part of the Croydon district, where the original type area occurs (White, 1959)[1]. Similar, and probably related, granites in smaller plutons elsewhere in the district are - Mooremount granite, in the headwaters of the Near Carron River, southeastern corner of CROYDON; Little Bird granite, 5 km north of Inorunie homestead in central GILBERT RIVER; Chadshunt granite, on the western side of the Gilbert River in northern GILBERT RIVER and southern STRATHMORE; Macartneys granite, along the road to Langlovale homestead east of Pleasant Creek in southeastern GILBERT RIVER; Olsens granite, in the southeastern and northeastern corners respectively of GILBERT RIVER and ESMERALDA; Dregger granite, 5 km southwest of Blackfellow Yards in eastern ESMERALDA; Illewanna granite, 3 km southeast of Snake Creek Mine in eastern ESMERALDA; and Bimba granite, 8 km southeast of Snake Creek Mine.

The Nonda granite (previously Nonda microgranite) is a melanocratic fine-grained marginal variant of the Esmeralda Granite, as now restricted.

Inorunie group

The Inorunie Sandstone of Laing & Power (1959)[2] is now regarded as being of group status; in addition, the original apparent mis-spelling of the

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1 White, D.A., 1959: New names in Queensland stratigraphy (Part 3). Australasian Oil and Gas Journal, 5(10), 31-36.

2 Laing, A.C.M., & Power, P.E. 1959: Inoruni Sandstone. In New names in Queensland stratigraphy (Part 1). Australasian Oil and Gas Journal, 5(8) 27-36.

unit's name (Inoruni) has been corrected. The nomenclature applied previously to constituent subunits has been varied because of unavailability of some names, and by transfer of others between subunits. The informally named sequence, in ascending stratigraphic order, is now - Dirie sandstone (previously Guela sandstone); Chulcee formation (previously Venture formation); Guela sandstone (previously Nannygoat sandstone); and Arrongulla formation (previously Chulcee formation).

OTHER ACTIVITES

Oversby participated in the pre-Fifth Australian Geological Convention field excursion in the Hamersley Basin and Pilbara Block from 9 to 16 August; he attended the Convention in Perth during the following week, and presented a paper entitled "Preliminary report on concordant barite and base-metal sulphide deposits in Proterozoic Einasleigh Metamorphics of the Werrington area, Georgetown Inlier, northeastern Queensland"; he also read a paper for J.J. Draper (Geological Survey of Queensland) co-authored by Mackenzie and Withnall on "Proterozoic shelf sedimentation in the Georgetown Inlier, northeastern Queensland".

Oversby and Withnall attended a conference on granites held at James Cook University, Townsville, on 18 and 19 September.

J.H.C. Bain, who was overseas throughout the year, published a paper entitled "Some new ideas on the age and origin of the Etheridge Goldfield, Queensland, and their exploration implications" in the Proceedings of the Australasian Institute of Mining and Metallurgy. Subsequently, a discussion clarifying some aspects of the data presented was prepared and published in the same Proceedings by Withnall.

VOLCANOLOGY

by

R.W. Johnson

PAPUA NEW GUINEA VOLCANIC GEOLOGY, PETROLOGY, AND TECTONICS

A wide range of activities was again undertaken by the Volcanology Subsection this year. These included: geological, petrological, and geochemical studies of individual volcanoes in Papua New Guinea; compilation of a geological data catalogue for the Tabar-to-Feni Islands north and east of New Ireland; compilation of historical records of pre-1944 volcanic activity in Papua New Guinea; completion of volcanological or petrological reviews for three different national and international projects, as well as a volume of papers in honour of the late R.J.S. Cooke and E. Ravian. BMR officers A.L. Jaques, W.D. Palfreyman, and D.A. Wallace participated in some of the activities on a part-time basis, and much of the work was undertaken with research workers in other institutions, notably R.J. Arculus and B.W. Chappell of the Australian National University.

STUDIES OF MANAM, LAMINGTON, BAMUS, AND LOLOBAU VOLCANOES

The petrology and geochemistry of a suite of mainly basaltic samples from Manam volcano, collected by C.O. McKee (Rabaul Volcanological Observatory), has been studied by Jaques and Johnson in collaboration with R. Hickey of the Massachusetts Institute of Technology (USA) and B.W. Chappell. Crystallisation of the magmas appears to have taken place under intensely water-undersaturated conditions, and $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ values do not provide conclusive evidence for a slab-derived component having played an important role in the chemical modification of the magma-source regions.

The 1951 cumulodome and other lavas of Mount Lamington have been studied petrologically, together with cumulate inclusions and pieces of the Papuan Ultramafic Belt contained in the 1951 dome (co-workers Arculus, Chappell, and McKee). New mineralogical and geochemical data provide convincing evidence that the andesites must have been significantly contaminated by the ophiolite, producing the fairly high Ni (25-70 ppm) and Cr (150-179 ppm) values in the andesites.

A comprehensive paper on Bamus volcano has been completed (co-authors R.P. Macnab, Arculus, R.J. Ryburn, R.J.S. Cooke, and Chappell). Bamus is a large stratovolcano that is similar in form and size to its neighbour Ulawun, but the rocks of the two volcanoes are quite different (Bamus has at least one boninite-like lava flow). Both volcanoes have evidently evolved independently of each other.

J.L. Banner of the State University of New York at Stonybrook (USA) completed a study of Lolobau Island for an M.Sc. thesis. Results are at present being compiled for a joint paper that will be co-authored by Johnson, A.E. Bence, and S.R. Taylor. Lolobau is a volcanic complex in which basalt, andesite, dacite, and rhyolite have been erupted throughout the evolution of the complex rather than one magma type dominating any particular period of the eruptive history.

VOLCANIC ISLANDS OF TABAR, LIHIR, TANGA, AND FENI

Geological surveys were made between 1969 and 1974 of the Tabar, Lihir, Tanga, and Feni island groups that constitute a dominantly alkaline volcanic chain roughly parallel to, and northeast of, the Tertiary island arc of New Ireland in northeastern Papua New Guinea. The islands consist mainly of Pliocene and Pleistocene lava flows and volcaniclastic deposits, but pre-middle Miocene volcanic rocks are known in the Tabar Islands. Quartz trachytes (the only silica-oversaturated rocks of the chain) represent the youngest extrusive rocks in each island group. Raised Pleistocene coral reefs form ringing terraces on many of the islands, and Miocene reef limestone is preserved on Simberi Island in the Tabar Islands.

Geological descriptions of the islands and whole-rock chemical analyses for 116 Tabar-to-Feni rocks (major and trace elements, and, for some rocks, rare-earth element abundances and $^{87}Sr/^{86}Sr$ values) have been compiled for production as a BMR Report. Electron-microprobe analyses of rock-forming minerals in many rocks have also been tabulated. The analysed alkaline rocks are mainly phonolitic tephrite and trachybasalt, but more mafic types are basanite, tephrite, alkali basalt, transitional basalt, and ankaramite. Authors of the compilation are Wallace, Chappell, Arculus, Johnson, M.R. Perfit, I.H. Crick, G.A.M. Taylor and S.R. Taylor.

HISTORICAL RECORDS TO PRE-1944 VOLCANIC ACTIVITY

A review by Arculus and Johnson on the roles of slab-derived components and crustal contamination in island-arc magmas was written and accepted for publication in Geochemical Journal. A major conclusion is that contamination by crust in the arc may be a more important process than addition of subducted material to the mantle wedge above downgoing slabs.

Another review, on rhyolites in Papua New Guinea, was accepted for publication in Journal of Geophysical Research (authors I.E.M. Smith (University of Auckland) and Johnson). Papua New Guinea's rhyolites have a wide range of compositions, are found in several different tectonic settings, and appear to have originated by both crystal fractionation and crustal melting.

Page proofs for 25 papers in the Cooke-Ravian Volume of Volcanological Papers were received and corrected. This volume was edited by Johnson, and is Number 10 in the Memoir series of the Geological Survey of Papua New Guinea. The volume is scheduled for publication in late 1981. Johnson also completed three general accounts - on volcanoes, andesites, and Papua New Guinea tectonics - for the Australian Academy of Science School Geology Project.

CONFERENCES AND SYMPOSIA

Johnson attended the COGS/AMSTAC workshop on 'Australia and Ocean Drilling' in Canberra on 10-12 March, and was rapporteur for the working group on active margins, marginal seas, and oceanic crust. He also attended the IAVCEI 'Arc volcanism' symposium held in Tokyo and Hakone, Japan, and was co-author of eight papers. Johnson participated in the UNESCO-sponsored seminar on 'Volcanic Hazard Appraisal in the Circum-Pacific' which was held during the IAVCEI symposium in Hakone, and there led the discussion on the proposal for a Western Pacific volcanological institute or network.

PETROLOGICAL, GEOCHEMICAL, AND GEOCHRONOLOGICAL LABORATORIES

Acting Supervisor: A.Y. Glikson

PROFESSIONAL STAFF: L.P. Black. B.I. Cruickshank, G.R. Ewers, John Ferguson (to August), A.D. Haldane (to July), A.L. Jaques, R.W. Page, P.A. Scott (to June), J.W. Sheraton.

TECHNICAL STAFF: M.J. Bower, N.J. Davis, F.De Souza (May to August), K.H. Ellingsen, J.L. Fitzsimmons, D.B. Guy, J.A. Haldane, N.C. Hyett (to February), J.G. Pyke, T.I. Slezak, T.K. Zapasnik.

PETROLOGICAL LABORATORY

PILBARA VOLCANIC GEOCHEMISTRY: PHASE I by A.Y. Glikson & A.H. Hickman (GSWA).

The first phase of the Pilbara project was completed in 1981; this included (1) production of the Record "Geochemistry of Archaean volcanic successions, eastern Pilbara Block, Western Australia" by A.Y. Glikson & A.H. Hickman (Geological Survey of Western Australia) (Record 1981/36); (2) a paper entitled "Geochemical stratigraphy of Archaean mafic-ultramafic volcanic successions' by A.Y. Glikson & A.H. Hickman (in: Second International Archaean Symposium, Perth, edited by J.E. Glover & D.I. Groves, in press), (3) a paper entitled "REE geochemistry and geochronology of Archaean silicic volcanics and granitoids from the Pilbara Block, Western Australia" by B.M. Jahn, A.Y. Glikson, J.J. Peugot, & A.H. Hickman (Geochemica et Cosmochimica Acta, in press), and (4) a paper entitled "Sm-Nd dating of the Talga-Talga Subgroup,

Warrawoona Group, Pilbara Block, Western Australia', by P.J. Hamilton, N.M. Erevsen, R.K. O'Nions, A.Y. Glikson, & A.H. Hickman. (in: Second International Archaean Symposium, Perth, edited by J.E. Glover & D.I. Groves, in press).

PILBARA VOLCANIC GEOCHEMISTRY: CLUSTER ANALYSIS by A.Y. Glikson

Cluster analysis of the Pilbara data was conducted according to the Bonham-Carter Q-mode scheme, aiming at (1) rock type differentiation, and (2) formation (unit) discrimination. The cluster analysis has proved an efficient method of discriminating between geochemically distinct rock types - for example, peridotitic komatiite, high-Mg basalt, tholeiitic basic rocks, dacite-andesite, and high-K rhyolite. However, exceptions occur, as reflected by the occasional inclusion of distinctly different lithological types within the same clusters. Thus, an overlap is observed between tholeiites and high-Mg basalts; in some instances the distinction between these types is reflected by their varying proportion in the different clusters, rather than in complete separation. This is in accord with observed compositionally continuous range. In contrast, peridotitic komatiites plot in distinct blocks on the dendograms. Little or no separation is observed between tholeiitic basalt, dolerite, and gabbro. Likewise, andesites and dacites tend to fall within the same clusters, as do dacites and rhyolites. In other instances, good separation is achieved between dacites and rhyolites or between same rock types with different chemical attributes, i.e. high-Al dacites or high-Ba dacites. Some separation is obtained between trondhjemites of the Mount Edgar Batholith and Duffer Formation dacites and rhyolites, suggesting overall chemical differences. Potassic rhyolites of the Wymand Formation plot in three distinct clusters in accordance with their geographic derivation from three different sections. By way of contrast with the rock type test runs, formation runs were aimed at investigating possible overall geochemical differences within single rock types in accordance with their stratigraphic (volcanic unit) and geographic (section) derivation. The results have proved disappointing, in that little overall correspondence is observed between single rock type attributes and stratigraphic/geographic source. However, this result cannot be interpreted in terms of detailed similarities. Thus, it is known that distinct units have diagnostic element characteristics, e.g. the high Ti and low K of North Star Basalt and Mount Ada Basalt tholeiites, high Al and K of some Gorge Creek Group tholeiites, low Zr in the Apex Basalt and Gorge Creek Group tholeiites, high Zr in the EB tholeiites, and low Cr in the HB tholeiites. It was concluded that these minor, but highly significant, differences are overshadowed by the otherwise overall similarities within individual rock types.

PILBARA VOLCANIC GEOCHEMISTRY: REE ANALYSES by A.Y. Glikson

Eighteen silicic volcanic rocks of the Warrawoona Group and ten associated plutonic rocks have been selected for geochemical and isotopic studies. The silicic volcanics of the upper silicic member of North Star Basalt are dated at 3560-3570 m.y. by the Rb-Sr and the Sm-Nd methods. The respective initial isotopic values are 0.7005 $\pm$ 5 (Sr) and 0.50810 $\pm$ 39 (Nd). This age is consistent with the stratigraphic interpretation that the Talga-Talga Subgroup, in which the North Star Basalt is the lowermost formation, is overlain by the Duffer Formation, whose age was well established at 3450 m.y. using the zircon U-Pb method. The new Rb-Sr data on six silicic lava samples yield an isochron of 3230 $\pm$ 280 m.y., with I_{Sr}=0.7007 $\pm$ 14. The age agrees with the zircon age within error limits.

The Rb-Sr ages of 2300-2400 m.y. obtained for rocks from the Panorama and Wyman Formations do not correspond to their initial eruption ages. Consideration of the geochemistry suggests that these ages represent the time of metasomatism associated with the widespread thermal event in this region about 2300-2400 m.y. ago. Geochemically, most of these analysed volcanic and plutonic rocks are of tonalite-trondhjemite-granodiorite composition, a typical feature of Archaean terrains. They generally show fractionated REE patterns, except the Panorama Formation rocks. Furthermore, the Wyman Formation rhyolites and the post-tectonic adamellites show significant negative Eu anomalies, suggesting a similar mode of magma generation and a probable genetic link between them.

Theoretical considerations suggest that these magmas could have been generated by partial melting of amphibolitic (or basaltic) sources, followed by fractional crystallisation. Although the Archaean granitic gneisses often possess mantle-like I_{Sr} values, the trace-element data indicate that they could not have been derived by direct melting of upper mantle materials. The immediate tectonic implication is that in any Archaean terrain, the formation of Na-rich continental crust must be preceded by the presence of basaltic crust. The occurrence of this basaltic crust is a matter of controversy. It might have been totally destroyed by repeated melting processes, or its remnants are now represented by the widespread mafic-ultramafic enclaves within the tonalite-trondhjemite batholiths.

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

Material collected during August-September, 1980, for phase II of the project by A.Y. Glikson and R. Davy (Geological Survey of Western Australia) included a total of 681 samples from the following units (in stratigraphic order):

Fortescue Group	(Maddina Basalt	
	(Nymerina Basalt	
	(Kylena Basalt	
	(Mount Roe Basalt	
Whim Creek Group	(Honeyeater Basalt	
	(Charteris Basalt	
Warrawoona Group	(Wyman Formation	
	(Euro Basalt)	Salgash Subgroup.
	(Apex Basalt)	
	(Duffer Formation	
	(Mount Ada Basalt)	Talga-Talga Subgroup.
	(North Star Basalt)	

Microscopic examination in thin section has been carried out of all rocks and a total of 515 samples was selected for major and trace-element analysis. The chemical work will be carried out during late 1981 and early 1982.

WEST ARUNTA GRANULITE/GNEISS STUDY by A.Y. Glikson

Plotting of petrological data on 1:25 000-scale aerial photograph overlays has been completed and compilations finalised for preparation of structural/petrological map sheets of the GLEN HELEN, NARWIETOOMA, and ANBURLA 1:100 000 map sheets. The material studies included the following groups:

Mount Hay basic granulite and anorthosite
Mount Zeil granulite-facies charnockitic gneisses
Redbank zone granulite facies blastomylonites
Redbank-Mount Zeil mylonites, phyllonites, and cataclastic gneisses
Teapot granite
Glen Helen migmatites

Haast Bluff metasediments

Electron-probe study of the metamorphic assemblages aimed at defining pressure-temperature conditions of recrystallisation and crustal environment have commenced.

PETROLOGY AND GEOCHEMISTRY OF IGNEOUS AND METAMORPHIC ROCKS FROM ANTARCTICA

by J.W. Sheraton

Petrological and geochemical studies of igneous and metamorphic rocks from Enderby Land and MacRobertson Land, in conjunction with the geological mapping program in Enderby Land, have largely been written up for publication. The basic petrographic data have been collated and will be used in the compilation of 1:250 000-scale maps of Enderby Land. Similar studies of rocks collected in the Davis/Prydz Bay area during the 1980/81 summer field season will allow comparisons to be made with the results of this earlier work.

MAFIC IGNEOUS ROCKS

A paper entitled "Geochemistry and geochronology of Proterozoic tholeiite dykes from East Antarctica: evidence for mantle metasomatism" (with L.P. Black) was submitted to Contributions to Mineralogy and Petrology.

Tholeiite dykes of the Vestfold Hills closely resemble those of Enderby Land. The majority appear to be equivalent to the Amundsen dykes of Enderby Land and are of generally similar age (~1200 m.y.). Also represented are high-Mg tholeiites, characterised by abundant orthopyroxene, which are petrographically virtually identical to certain Enderby Land dykes which have given a Rb-Sr age of 2350 ± 48 m.y. Rare alkali basalt dykes are of unknown age but may be analogous to Phanerozoic alkali basalts of the northern Prince Charles Mountains.

In the southern Vestfold Hills, the tholeiite dykes have been largely recystallised under granulite-facies conditions. Irregular aggregates of garnet are commonly developed, but there has apparently been little deformation. These metamorphic effects are thought to have been contemporaneous with the late Proterozoic metamorphism which formed the gneisses along the coast southwest of the Vestfold Hills.

FELSIC GNEISSES AND GRANITIC INTRUSIVES

A number of compositional features of felsic gneisses of the East Antarctic Shield are relevant to studies of crustal evolution during the Precambrian.

Granulite-facies orthogneisses which make up much of the Archaean Napier Complex of Enderby Land comprise two groups. The most abundant ranges in composition from tonalite, through granodiorite, to (subordinate) granite and is characterised by marked depletion in Y (and, by implication, heavy rare earths). The chemical features of these depleted gneisses can be explained by hydrous partial melting of a garnet-bearing source (garnet amphibolite or eclogite), combined with hornblende and subordinate plagioclase fractionation. Many of the compositional differences between the tonalites and granodiorites may be due to the involvement of a fluid phase enriched in lithophile elements (K, Rb, Ba, Th, and U). Gneisses of similar composition are common in Archaean metamorphics of, for example, Greenland and northwest Scotland, and are thought to represent primitive sialic crustal material ultimately derived, by a two-stage melting process involving mafic crustal rocks, from the mantle.

The second (undepleted) group, predominantly of trondhjemitic to granitic composition, does not show Y depletion, and is relatively rich in TiO_2, total FeO, Zr, and Nb, poor in CaO and Sr, and has high Ca/Al. These probably originated by remelting under relatively dry conditions of a depleted felsic gneiss plus mafic granulite source in the lower crust. Both gneiss groups show metamorphic depletion of Rb (relative to K), Th, and U.

Proterozoic, post-orogenic intrusive rocks of Enderby Land are mostly granite or granodiorite, and are commonly quite mafic and enriched in Fe. Some are unusually potassic, being similar in this respect to the Mawson Charnockite, and many are high in P_2O_5, Y, Zr, Nb, La, and Ce, reflecting the abundance of accessory minerals such as apatite, zircon, and allanite. Th and U are commonly low. Thus, there is a closer resemblance in composition to the undepleted, rather than the depleted, gneiss suite, and these intrusives were probably also derived by relatively dry melting of older sialic crustal rocks.

Late Archaean gneisses of the southern Prince Charles Mountains belong to the undepleted suite and include ferrohastingsite-bearing granite-gneisses of clearly intrusive origin which have particularly high TiO_2, Y, Zr, Nb, La, and Ce. Such undepleted gneisses may be representative of a higher crustal level than that exposed in Enderby Land (their metamorphic grade rarely exceeds amphibolite facies) and they may be underlain by more depleted gneisses. Relatively dry partial melts of lower crustal rocks would tend to rise to higher crustal levels before crystallising. The well known fluid-induced upward migration of lithophile elements (K, Rb, Th, U, etc.) would also contribute to the compositional zoning of the crust.

Upper Proterozoic granulite-facies gneisses of the Rayner Complex in Enderby Land include many of the depleted type and apparently represent re-metamorphosed Archaean rocks, as is also suggested by field relations. In contrast, most gneisses of similar age in MacRobertson Land cannot be re-metamorphosed Archaean of either depleted or undepleted type. They include a large proportion of felsic gneisses derived from sedimentary protoliths, either directly or by partial melting, whereas Archaean gneisses are almost exclusively of igneous origin. Unlike the latter, few have sodic compositions. These compositional differences are consistent with the observed increase in the proportion of sediments among crustal rocks with time. Archaean metamorphics of East Antarctica include a relatively small proportion of sedimentary types, and, in the southern Prince Charles Mountains at least, metasediments of possible late Archaean age mostly appear to have unconformable relationships with the granitic basement gneisses. Paragneisses and other metasediments are distinctly more abundant amongst Proterozoic metamorphics of MacRobertson Land. Similar relationships have been observed in the Davis area of Princess Elizabeth Land, where Archaean gneisses of the Vestfold Hills are largely of igneous derivation, although they include a paragneiss component. In contrast, nearby late Proterozoic metamorphics (of similar age to those of MacRobertson Land) include a much higher proportion of aluminous paragneisses.

<u>ALKALINE ULTRAMAFIC ROCKS PROJECT</u> by John Ferguson (to August) and A.L. Jaques.

The aims of this project are to research the geology, petrology, geochemistry, and geochronology of alkaline ultramafic rocks throughout Australia to gain an understanding of their distribution, nature, and origin, and to provide a useful framework for diamond exploration.

Results of research on the kimberlitic rocks of southeastern Australia were reported in detail in the 1980 Annual Summary (BMR Report 230). It was suggested that the steep palaeogeotherms indicated from nodule assemblages, and the shallow levels of magma segregation postulated for the kimberlitic rocks of southeastern Australia (60-70 km), make it unlikely that diamondiferous kimberlite of Permian or younger age will be found in southeastern Australia. The exception to this was the kimberlite in the Euralia (South Australia) area where magma compositions suggest formation at greater depth (> 125 km). Studies of lower crustal nodules in the South Australian kimberlitic rocks have continued to more closely define palaeogeotherms and the nature of the deep crust. A paper dealing with the detailed petrology and geochemistry (including

REE) of mafic and salic crustal nodules by John Ferguson, and R. Arculus and B. Chappell (both ANU), is nearing comp ion.

The recent discovery of diamond in kimberlite in the Fitzroy area of the West Kimberley region of Western Australia has focused attention on the ultrapotassic rocks of the province, and many new intrusives, both kimberlitic and lamproitic, have been discovered. Since the lamproites are commonly thought to have been derived from kimberlite, the relationship between lamproite and kimberlite is of prime significance to diamond exploration. Little has been published on the suite since the original descriptions by Prider and associates. At present the age and time span of the magmatic activity, and the tectonic controls on the distribution of the suite, are poorly known.

Petrological and geochemical studies of rocks from this province have so far focused mainly on the leucite lamproite bodies discovered by BMR during regional mapping of the Kimberley region in the late 1960s. Rock types range from fitzroyite (phlogopite-leucite lamproite) through wyomingite (diopside-phlogopite-leucite) to cedricite (diopside-leucite) and through wolgidite (diopside-phlogopite-magnophorite-leucite) to mamilite (magnophorite-leucite lamproite). Olivine-bearing (now replaced by nontronite, silica, or serpentine) lamproites also occur and commonly have phenocrysts/microphenocrysts of diopside and leucite. Amphibole appears to be restricted to the groundmass except in the more evolved (felsic) lamproites where it is a major phase. Priderite is ubiquitous, and other accessory minerals include wadeite, perovskite, and calcite. Secondary minerals include quartz, chalcedony, opaline silica, zeolite, calcite, serpentine, K-feldspar, nontronite, chlorite, and serpentine. Phlogopites typically show a wide range in Al and Ti contents; phenocryst cores are generally poorer in Ti and Fe, and richer in Al and Mg than groundmass phlogopite which contains up to 10 wt % TiO_2. Diopside is characteristically poor in Al and rich in Ti (> 1 wt % TiO_2). All the lamproites are characterised by very high K_2O (generally K_2O >Al_2O_3) and TiO_2. contents, and generally have low Al_2O_3 and CaO (except where carbonated) and very low Na_2O contents. The high K_2O contents are matched by extreme enrichment in Ba, Rb, Sr, LREE, Zr, and Nb; Y contents are low (> 20 ppm) indicating extremely fractionated REE patterns. Ni and Cr contents range from comparatively high values (e.g., 300 ppm Ni, 500 ppm Cr) to low values, typically 50 ppm in more evolved felsic lamproites. Petrologic and geochemical work are continuing.

The leucite lamproite bodies are believed to have been intruded at comparatively low temperature. However, at one locality where a small plug of fine-grained lamproite intrudes Devonian limestone a narrow high-temperature contact aureole is developed. Minerals developed in the calc-silicate aureole rocks include spurrite, merwinite, gehlenite, and periclase, indicating a high-temperature and low-pressure origin. Work is continuing to more closely constrain intrusion temperatures.

GOAT PADDOCK CRYPTOEXPLOSION STRUCTURE by John Ferguson (to August), A.L. Jaques, and S.N. Sheard (Geophysics).

The aim of this project, being undertaken in collaboration with D.J. Milton (USGS) and R.F. Fudali (Smithsonian Institute) is to study the nature and origin of the Goat Paddock cryptoexplosion structure which lies at the northern edge of the King Leopold Range/Leopold Range junction in the Kimberley district of Western Australia. Results of geological mapping were reported in the 1980 Annual Summary (BMR Report 230).

Compilation of a detailed geological map and detailed interpretation of geophysical profiles were delayed pending preparation by the USGS of an accurate topographic map from 1:5 000-scale aerial photography.

Aeromagnetic profiles flown by the Geophysical Branch reveal that there is no major magnetic anomaly associated with the crater. The amplitude of the anomaly is such as to discount the possibility of any large, near-surface igneous intrusive such as a kimberlitic plug associated with the crater. However, the survey revealed three 'dipole-type' anomalies within the crater on the north-south profile which are at this stage unexplained. Work is continuing.

BMR-HOLLMAYER METEORITE STUDY, by A.L. Jaques and M.J. Fitzgerald (University of Adelaide)

Work continued on the description and classification of 57 previously undescribed meteorites held in the BMR Museum. Two papers were prepared and submitted for publication. Abstracts of the papers are given below.

THE NILPENA UREILITE, AN UNUSUAL POLYMICT BRECCIA: IMPLICATIONS FOR ORIGIN

Nilpena (173 g), a new ureilite find from the Parachilna area of South Australia, is an unusual polymict breccia containing polymineralic aggregates, mineral fragments, and achondritic and chondritic lithic enclaves in a dark, C-rich matrix. The polymineralic aggregates consist of equigranular-textured olivine Fa_{20}, and pigeonite $En_{75}Wo_9Fs_{16}$, and exhibit evidence of shock in the form of undulose extinction and kink-banding. Monomineralic fragments consist of olivine Fa_{19-24} (with highly forsteritic rims up to Fa_3) and pigeonite, and appear to be derived by brecciation of the polymineralic aggregates. The enclave material consists of lithic granular olivine fragments, porphyritic enstatite fragments (either enstatite chondrite or aubrite), olivine-clinobronzite fragments resembling an H3 chondrite, and eucrite-like lithic fragments composed of plagioclase An_{98}, salitic clinopyroxene $Wo_{48.5}En_{31.4}Fe_{20.1}$ and olivine Fa_{49-53}. The matrix contains kamacite (generally rich in P), schreibersite, and troilite. The texture of Nilpena suggests formation by disruption of a olivine-pigeonite granular aggregate while the presence of the diverse chondritic and achondritic enclave material suggests an origin as a surface or near-surface breccia. Like other ureilites Nilpena is markedly differentiated with respect to cosmic abundances, but is significantly enriched in Ba and LREE. A lack of correlation of lithophile elements with Fe/(Fe + Mg) ratio among ureilites suggests that the differentiation was not caused by varying degrees of partial melting of a homogeneous source. A cumulate origin therefore seems more plausible.

TIBOOBURRA, A NEW AUSTRALIAN METEORITE FIND, AND OTHER CARBONACEOUS CHONDRITES OF HIGH PETROLOGIC GRADE

The chemistry and mineralogy of Tibooburra, a previously undescribed meteorite find from western New South Wales, is shown to be a carbonaceous chondrite. Tibooburra belongs to the Vigarano subgroup of the carbonaceous chondrites and on the basis of its opaque mineralogy appears to be oxidised. Petrological evidence suggests that, like the Allende meteorite, Tibooburra has experienced greater metamorphic effects than other CV3 meteorites. Chemical analysis shows that the bulk composition of the meteorite is intermediate between the CO and less altered CV chondrites. This transitional nature is exhibited by several elements and is convincingly displayed by the multivariate techniques of cluster analysis and principal component analysis. Thus, Tibooburra resembles several other CV chondrites such as Coolidge and Karoonda which have experienced pronounced metamorphic effects. Tibooburra is classified as a CV3 chondrite, and it is suggested that, like these other meteorites, Tibooburra accreted early in the history of the Vigarano parent body. As a result these meteorites contain greater quantities of high temperature Ca-Al-rich inclusions but less low-temperature matrix and volatile phases. Furthermore, in these meteorites both the matrix and magnesium silicate phases appear to be more iron-rich than those in later accreted meteorites. Subsequently, these deeper-seated meteorites experienced more pronounced metamorphic effects than those located in shallower portions of the parent body.

FELSIC IGNEOUS ROCKS OF THE MOUNT ISA INLIER by L.A.I. Wyborn

THE KALKADOON-EWEN GRANITES (with R. Page)

These are the oldest granites in the Mount Isa Inlier. They are comagmatic with the Leichhardt Metamorphics and were intruded at about 1850-1870 m.y. (U-Pb zircon date). The primary mineralogy is rarely preserved, and a complete gradation can be observed from chlorite-epidote mineralogy of greenschist facies to hornblende-biotite of amphibolite facies. The metamorphic event which produced this change took place between 1600 and 1670 m.y. ago (Rb-Sr date). The granites and comagmatic volcanics are restricted to a zone some 300 km long by 40 km wide, and are remarkably uniform in composition reflecting a uniform source region at depth. The granites are true minimum melts containing most of the mafic minerals as restite phases. This, combined with the lack of pegmatites, suggests that a fluid phase capable of concentrating ore minerals probably never developed, and hence these granites would not be expected to be prospective.

GEOCHEMISTRY OF THE FELSIC VOLCANICS OF THE DUCHESS REGION (with R. Bultitude).

On the basis of geochemistry, five major volcanic rock groups are recognised. Group I constitutes the Leichhardt Volcanics, which are characterised by high Sr and low Zr, and are identical to the Leichhardt Metamorphics north of Duchess and some analyses of the Tewinga Group rocks (undivided) near Duchess. Group II consists of the Argylla Formation volcanics plus others within the basal Mitakoodi and Ballara Quartzites and the lower Corella Formation. Chemically they are distinct, having high Zr and Nb but low Sr. Group III consists of the Bottletree Formation volcanics which have high values of Ba, Sr, Zr, and Nb. Group IV occurs within the Corella Formation northeast of Duchess and is noted for low Sr and Zr but high Nb and is not unlike nearby plutons of the Wonga Granite. Group V is represented by the Carters Bore Rhyolite, which has anomalously high K_2O but relatively low Zr not unlike the Fiery Creek Volcanics, the Alhambra Member of the Quilalar Formation, and the tuff marker beds of the Mount Isa Group to the north of

If these chemical comparisons can be shown to correlate with time, they will be important in helping to resolve stratigraphic correlations in the Mount Isa region.

SUBCRUSTAL STUDIES

As granites are partial melts of the lower crust they tend to image their source region, and hence variations in composition within the granites on a regional scale can be interpreted as reflecting changes at depth. Preliminary results suggest that the source region beneath the Kalkadoon-Leichhardt block is extremely uniform, extending over an area about 300 km long by about 40 km wide. The elongate Sybella Granite to the west is also relatively uniform in composition and comes from another extensive area of crust which differs in composition from that of the Kalkadoon-Leichhardt source. However, the granites that intrude the Eastern Succession are not as uniform in composition and differ from pluton to pluton, reflecting a heterogeneous lower crust. It is significant that studies on the mafic intrusive rocks show similar trends - i.e., the dolerites in the Eastern Succession are heterogeneous and contrast with the more uniform compositions of the dolerites and mafic extrusives of the basement block and the Western Succession.

ECONOMIC POTENTIAL

The felsic igneous rocks can be divided into two major groups: I-type derived by partial melting of infracrustal material, and A-type derived by melting of the residue remaining after the removal of the I-type melts. Economically the A-type magmas (e.g., Argylla Formation) and the higher temperature I-type magmas (Hardway Granite, Naraku Granite) seem capable of concentrating elements such as Cu, Pb, Zn, and U. However, suitable environments for depositing these elements are also necessary, and these occur where the volcanics are extruded in a submarine environment or where the granites intrude calc-silicate rocks (mainly Corella Formation).

<u>BASIC IGNEOUS ROCKS OF MOUNT ISA</u> by D.J. Ellis & L.A.I. Wyborn

The basic igneous rocks of the Precambrian Mount Isa region, occur in 3 parallel, north-south trending linear tectonic units - the basement block, the Western Succession and the Eastern Succession. Basic volcanic rocks crop out extensively in each of these units and are cut by dolerite dykes and sills. At least three distinct episodes of basic igneous activity are recognised in each succession, and the volume of igneous material decreased with time.

Olivine-and quartz-tholeiites predominate, and minor andesites occur in the Eastern Succession. Systematic spatial and temporal variations in the compositions of these rocks are recognised. The rocks in the Western Succession were most probably erupted on the edge of the continental margin, and display the least chemical variations with time, whereas those farther east display greater variations.

SELWYN METAMORPHICS by A.L. Jaques.

The Selwyn Range, which lies at the deformed eastern margin of the Mount Isa orogen, consists of pelitic/psammitic, calc-silicate, and basic igneous rocks which have been regionally metamorphosed (polymetamorphic) to amphibolite grade and intruded by granite plutons. Three metamorphic zones have been recognised in the main prograde sequence: a low-grade (biotite) zone equivalent to upper greenschist facies, an andalusite-almandine-staurolite zone of amphibolite grade, and an eastern upper amphibolite grade zone (sillimanite and finally sillimanite-K-feldspar). Regional isograds are unrelated to the dominantly post-metamorphic granites; however, the axis of the granitoid belt coincides roughly with zones of higher metamorphic grade. Superimposed on the prograde sequence is a variable retrograde assemblage related to later folding events. Comparison with petrogenetic grids of experimentally determined univariant curves and invariant points indicates metamorphic pressures of 3-4 kb; this estimate is supported by the 4 kb pressure calculated from various geobarometers for the higher-grade rocks. Cation exchange equilibria (mainly garnet-biotite) indicate equilibration temperatures of 450-680°C for the prograde sequence; the staurolite and almandine isogrades are estimated to be at 550°C, the sillimanite isograde at 600°C, and the K-feldspar isograd at 660°C. These values are in good agreement with values obtained from experimentally determined critical dehydration reactions. The high geothermal gradient implied for the Selwyn Range rocks (450-500°C/km) is believed to be due to subjacent basic magmatism associated with crustal attenuation and rifting.

X-RAY DIFFRACTION LABORATORY by J. Fitzsimmons

250 analyses were carried out during the reporting period. A conversion of the electronics in the XRD unit to a transistorised system was made in late 1980. Work has proceeded with computerisation of the automatic sample loader window of the XRD unit. The first stages of both the hardware

and the software adaptations have been completed, and testing is in progress. It is intended that this system be tied into the "Data Base Magnetic Tape" of the Joint Committee on Powder Diffraction Standards. There has been an increase in interest in clay analysis, and in powder camera work.

PETROCHEMICAL COMPUTER PROGRAMS FOR HP9825A DESKTOP CALCULATOR by A.Y. Glikson

A BASIC program package has been completed in conjunction with data processing and figure and table preparation for the Pilbara Geochemical Project. The basic storage and retrieval programs to which these programs are linked were developed by M.J. Owen, as were the X-Y and X-Y-Z plotting programs, mean and standard deviation and correlation coefficient program, CIPW program, and tabulation program. The following petrochemical programs by A.Y. Glikson are now available:

(1) Frequency distribution plots program
(2) Geochemical-stratigraphic columnar plots program
(3) LMPR (log molecular proportions) plots and deviation indices program
(4) Chondrite-normalised element ratio plots program
(5) Mantle Mg number from FeO-MgO plots
(6) Mantle trace elements abundance program
(7) Fractional crystallisation of basic magma and primary magma trace-element levels calculation program
(8) General equilibrium partial melting program

During the year geochemical data storage has been programmed for the HP9885M disc.

THIN-SECTION LABORATORY by N.J. Davies

The thin section laboratory was closed for a substantial period up to November 1980, owing to a lack of a technician to operate it. In December and January four weeks were spent by N.J. Davies at the Geology Department, ANU, training in the use of the Logitech LP 30 thin-sectioning equipment. Four-hundred-and-forty normal thin sections and 400 polished thin sections were made during the period February-September, 1981. No updating of equipment was made during the year.

GEOCHEMICAL LABORATORY

ARALUEN GEOCHEMICAL PROJECT by B.I. Cruikshank

The geochemical survey of ARALUEN commenced in 1977, the objectives being to gain an understanding of geochemical dispersion patterns in temperate terrains and to generate data to assist future exploration in, and economic assessment of, the area.

About 920 soil samples were collected on more or less systematic grid spacings over tableland areas around the Shoalhaven River and in the Araluen Valley, where optimum soil development could be expected. Here the underlying or parent rock units are predominantly volcanics and granites. The analytical data were regrouped by rock unit, showing that background geochemical parameters for soils over individual rock units can differ markedly from those of the total population.

Six areas anomalous in Pb and Zn, or As (± Cu, Bi, and Sn) have been defined. Three Pb-Zn anomalies occur over the Silurian volcanics, one of these being the Krawaree Pb-Zn prospect. An arsenic anomaly also occurs over volcanics but may be associated with the nearby Braidwood Granite. The remaining anomalies occur over granites, and include the Majors Creek Goldfield to the north of Majors Creek township (anomalous in Cu, Pb, Zn, As, and Au).

Five-hundred-and-ten stream-sediment samples were collected from over most of the Sheet area. These were regrouped into 13 separate catchment areas (e.g., west of Shoalhaven, east of Shoalhaven, etc.), showing that marked differences in the background geochemical parameters occur over the Sheet area.

Three large areas anomalous in As (± Pb, Zn, Cu, and Sn) were defined: in the Bendethra area, west of the Buckenbowra River, and near Merricumbene. Given the association of Au and As in the Majors Creek Goldfield, these areas are of prime interest. A Pb-Zn anomaly in the Oulla-Burra Creek area appears to be associated with the Donovan Basic Complex.

With one exception, stream-sediment samples collected over the tableland areas did not indicate the presence of the soil anomalies.

Two BMR Records, one a general Record giving summary statistics and interpretation and the other a microfiche compilation of soil and stream-sediment data, are being prepared.

REGIONAL GEOCHEMICAL SURVEYS by B.I. Cruikshank

BMR has been doing systematic regional geochemical surveys in northern Australia since 1972. Commencing with orientation work in the Georgetown and Westmoreland areas in 1972-73, regional stream-sediment surveys were carried out in the Georgetown area in 1974, 1976, and 1980; in the Westmoreland area in 1975; and in the Mount Isa area in 1978. An orientation survey was carried out in the Pine Creek area in 1979. The progress of these projects is summarised in Figure M9.

This year has been essentially a year of consolidation highlighted by the publication of the GEORGETOWN (4 sheets) and GILBERTON (4 sheets) geochemical maps and the explanatory record of the SEIGAL and HEDLEYS CREEK surveys. A compilation of the MAMMOTH MINES analytical and sampling data will soon be released as a microfiche Record.

Data from the GEORGETOWN, FORSAYTH, and GILBERTON surveys have been merged and are being re-evaluated. This involves some 3600 samples from an area of about 9000 km^2 of the Georgetown Inlier. The trace-element geochemistry of major rock units in these Sheet areas is also being studied and will be related to the stream-sediment geochemistry.

The re-evaluation has produced more realistic regional geochemical parameters which have been used to compile geochemical anomaly maps for inclusion with the special 1:250 000-scale map that is being produced of the central part of the Georgetown Inlier.

RANGER I BIOGEOCHEMISTRY AND SOIL GEOCHEMISTRY by B.I. Cruikshank and J.G. Pyke

This project aims to evaluate biogeochemical and geobotanical methods as applied to the search for uranium in the Pine Creek Geosyncline. Botanical sampling was carried out over the then undisturbed Ranger I, No. 3 orebody and adjacent barren areas. Control was provided by samples from an existing company soil grid over the orebody and by samples collected in the barren areas.

Preliminary analyses indicate that uranium may be concentrated in the leaves of a number of species of eucalypts, but not in the foliage of other plant species growing over the orebody.

A number of methods for the analysis of uranium by X-ray fluorescence spectrometry have been evaluated and the most promising, for convenience and reproducibility, appears to be the direct pelleting of powder material, and using extended instrument counting times and modified mass absorption correction procedures.

The samples are being ground and pelleted and will be analysed as instrument time is available.

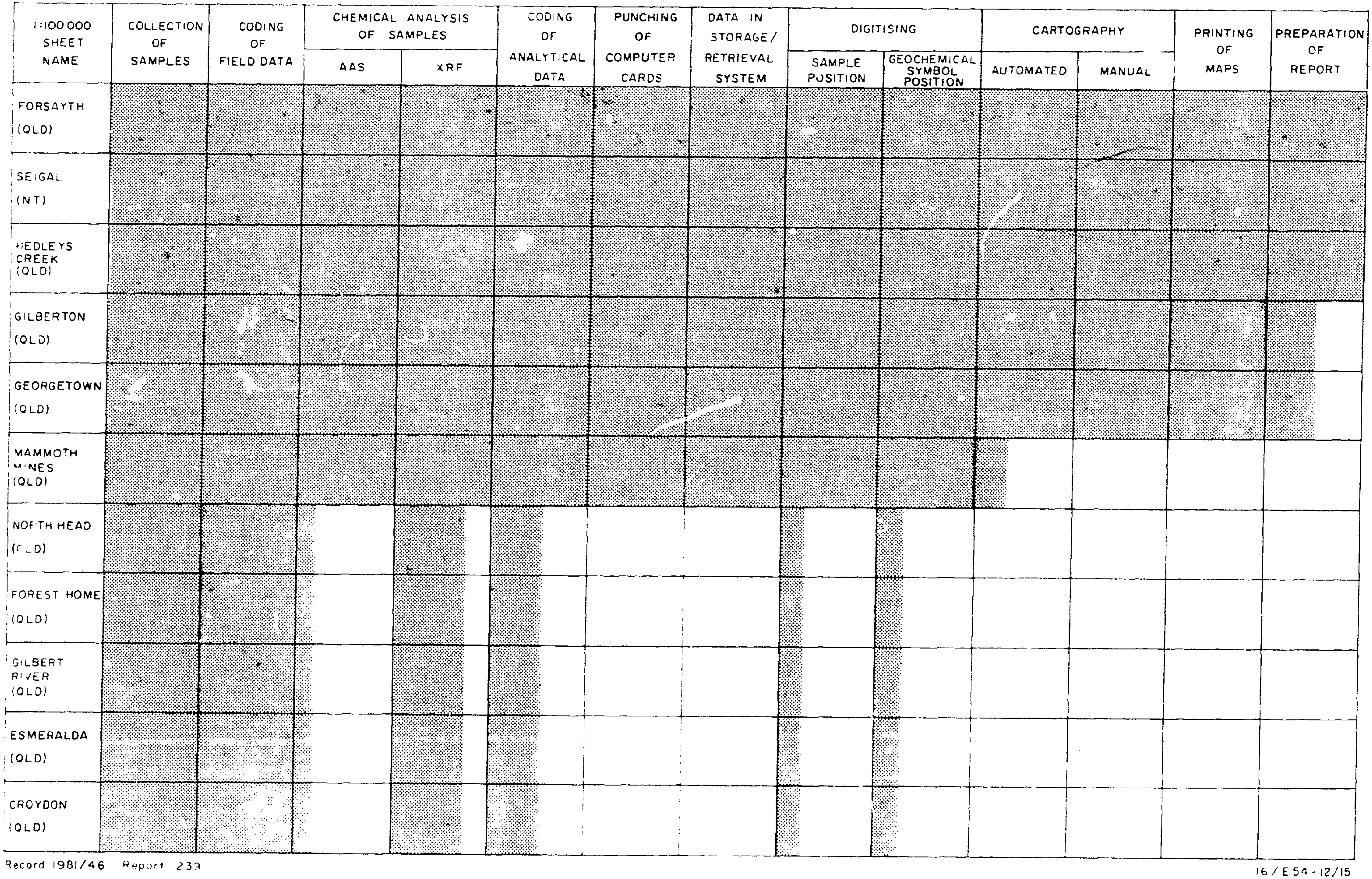

Fig. M9 Current status of BMR's regional stream-sediment surveys.

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

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

Petrographic and electron microprobe work have shown that the mineralisation at Nabarlek is associated with chlorite. This association has been described at Jabiluka, Ranger, and Koongarra, but unlike these deposits, the Nabarlek orebody has been extensively sericitised at a later time. This sericitisation is associated with hematite alteration of the replaced chlorite, and may be the younger alteration episode dated by Page at around 920 m.y. for Nabarlek and not seen in the other deposits. Different generations of chlorite have been identified and several varieties can be characterised chemically. Probework has confirmed the presence of trace amounts of native copper and cobaltite, neither of which have been previously identified. Autoradiographs have been successfully used to indicate the distribution of U mineralisation on a megascopic scale and to facilitate probe studies.

The reported occurrence of graphite at Nabarlek has not been confirmed by this study. However, minor carbonates (siderite, dolomite, and calcite) have been found veining wallrock and occupying fractures within massive uraninite. Limited isotopic work on these carbonates (in conjunction with T.H. Donnelly) may indicate whether organic carbon was present during the main mineralising event. Sulphur and oxygen isotope studies have been abandoned owing to the unsuitability of the samples and the inherent difficulties in interpreting very few results.

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* In URANIUM IN THE PINE CREEK GEOSYNCLINE. IAEA, Vienna, 563-74.

Analytical problems caused by the high levels of uranium in most samples have been partly resolved, largely due to the efforts of B.I. Cruikshank and J.G. Pyke. XRF major and trace-element data are quantitative where samples contain less than 1% U. For U levels between 1% and 10%, AAS major-element analysis and XRF trace-element analysis give semiquantitative results, whereas U concentrations in excess of 10% allow only qualitative results. For intensely mineralised samples, the interelement corrections are so large for some elements (i.e., Rb, Sr, Th, Nb, Y, As) that these data have been discarded.

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

The main objectives of this project are:

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

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

Whole-rock analysis (major elements plus Ba, B, F, Ce, Co, Be, Cu, Ga, Li, La, Mo, Ni, Pb, Br, Sn, Sr, Th, U, V, W, Y, Zn, Zr, CO_2, $H_2O^{\pm}$) and petrographic descriptions have been completed for 344 samples collected from shallow stratigraphic and deep diamond-drillholes across the Pine Creek Geosyncline. The drilling was carried out by BMR and NTGS over the past 10 years, and provided material removed from areas of known mineralisation, and from below the weathering zone. The analytical work has been possible through the assistance of B.I. Cruikshank, K.H. Ellingsen, C.R. Madden, J.G. Pyke, and T.I. Slezak.

Using the HP 9825, a data file giving complete sample data (i.e., BMR registered number, drillhole data, formation, rock type based on petrography, AMG reference, 100 000 Sheet area, nd bibliographic reference for each sample) and analytical data has been created. The file has been periodically updated; the most recent refinements were made by the Pine Creek Party to the Lower Proterozoic stratigraphy of the Pine Creek Geosyncline.

The statistical evaluation and interpretation of the data in terms of the objectives outlined above will commence shortly.

ANALYTICAL LABORATORY by J.G. Pyke & B.I. Cruikshank

STAFF: B.I. Cruikshank, F.R. D'Souza (4 May to 26 August), G.R. Ewers, J.A. Haldane (from 10 March), J.G. Pyke, T.I. Slezak.

During the year 3030 samples were analysed for a total of 47 000 element determinations. Of these, 2300 samples were from the Georgetown Geochemical Project.

X-RAY FLUORESCENCE SPECTROMETRY

One-hundred-and-ninety-two silicate samples were analysed on the major-element program.

Trace elements were determined on 2810 samples (33 330 element determinations).

ATOMIC ABSORPTION SPECTROPHOTOMETRY

Trace elements were determined on 1100 samples (9640 element determinations).

CHEMICAL METHODS

Sixty-six silicate samples were analysed for CO_2 and $H_2O^{\pm}$. One-hundred-and-fifty-one silicate samples were analysed for FeO.

GEOCHRONOLOGICAL LABORATORY

GENERAL

The work of this group hinges on the successful employment of the U-Pb and Rb-Sr isotopic dating approaches on several Geological Branch projects in Queensland, Northern Territory, Antarctica, Tasmania, and New South Wales. This year some preliminary Sm-Nd studies have also been made.

Most of the effort in the sample preparation/mineral separation area is directed towards the extraction of zircon and monazite from a variety of igneous and metamorphic rocks. During the year this section of the group undertook 20 complete zircon separations, 12 other mineral separations, and about 100 total-rock crushings. Special measures were taken to separate several uranium-rich mineral phases from mineralised skarns of the Mary Kathleen orebody. The remainder of the group continued to use the joint isotope laboratory facilites in the Research School of Earth Sciences, ANU. Continuing co-operation and assistance from the Director and staff of the School have greatly benefited BMR's activities. Delivery of the jointly ordered ANU/BMR Nuclide automated mass spectrometer (for which BMR are paying about one third of the initial capital cost) is currently late by several months owing to delays in production.

During the year, Page and Black initiated a collaborative program with Dr A. Gleadow (University of Melbourne). This involves measurement of fission-track ages on apatites from Proterozoic and Archaean rocks studied by the U-Pb zircon method. The aim is to investigate any systematic relationship between the apatite ages and the lower concordia intercept ages obtained from the zircon work, as it is felt that these age parameters may generally reflect Palaeozoic to relatively recent uplift histories.

PINE CREEK PROJECT (R.W. Page, M.J. Bower, T.K. Zapasnik, D.B. Guy)

Further Rb-Sr work was undertaken on selected granitic rocks and gneisses from the Litchfield Complex to investigate whether any late Archaean components are present, as at Rum Jungle and in the Alligator Rivers region. The new results have been obtained in collaboration with A.O.G. Minerals Pty Ltd and contribute to what is now a good reconnaissance of this prospective complex. The new total-rock data acquired this year confirm our earlier interpretations that the Litchfield Complex is part of the granitoid development which postdates the Lower Proterozoic Pine Creek Geosyncline, and is about 1820 m.y. old. Rb-Sr biotite results are very similar to the total rock ages, indicating little or no thermal history since emplacement. Some zircon work is now being undertaken to complement these Rb-Sr measurements.

In last year's Annual Summary (BMR Report 230), mention was made of Rb-Sr work on the Zamu Dolerite, which provided the first (minimum) estimate of about 1940 m.y. for the age of Lower Proterozoic sedimentation in the Pine Creek Geosyncline. This year, zircons have been extracted from one of the many felsic tuffaceous units in the Lower Proterozoic sequence. So far, only a small amount of analytical work has been done on this material. The igneous morphology of the zircons and the U-Pb systematics of the preliminary data suggest that their U-Pb age will support the Zamu Dolerite information and provide a further stratigraphically meaningful time-marker for the Lower Proterozoic of northern Australia.

<u>MOUNT ISA PROJECT</u> (R.W. Page, M.J. Bower, T.K. Zapasnik, D.B. Guy, N.C. Hyett).

FELSIC VOLCANIC SEQUENCES

This year, work was completed on the U-Pb isotopic study of zircons from superposed felsic volcanic units in the Mount Isa Inlier. The new data and interpretations are based on U-Pb analyses of 66 zircon fractions from 12 stratigraphic levels of extrusive felsic volcanism, representing the principal volcanic components from throughout the 30km-thick stratigraphic pile. These results allow detailed definition of the chronology of the major depositional cycles, and throw some light on the question of stability of zircon U-Pb systems in felsic volcanic sequences at low- and medium-grades of regional metamorphism.

In general, the volcanic zircon data define linear or sublinear arrays that can be explained as a result of a two-stage process, of initial volcanic crystallisation and later (mid Palaeozoic to Mesozoic) Pb loss. The following conclusions can be reached:

(i) In general, the zircon ages are in accord with known stratigraphic constraints.

(ii) The earliest recognised volcanic cycle (Leichhardt Metamorphics) composes part of the oldest known structural element in the inlier, and has an age of 1867 ± 5 m.y.

(iii) The second major cycle of volcanism can be clearly identified as from 60 to 80 million years younger than the first. It is defined in two regions - (a) in the west, where 1790 ± 9 m.y. and 1808 ± 20 m.y.-old metadacites (Bottletree Formation) unconformably overlie the Leichhardt Metamorphics, and (b) in the east by a belt of rhyodacitic volcanics (Argylla Formation) which overlies the same basement and are dated at 1783 ± 5 m.y.

(iv) In all, the volcanic crystallisation ages interpreted from the zircon data define an evolutionary framework spanning 270 million years. All the known Proterozoic supracrustal sequences in the Inlier were deposited within this interval.

(v) The elongate volcanic belts which can be traced for more than 300 km, represent geochronologically definable cycles of volcanism, within which the ages are fairly constant, varying by only 10 to 20 million years.

(vi) Zircon U-Pb systems in felsic volcanic rocks can withstand greenschist and most amphibolite facies alteration events. In some amphibolite facies terrains, isotopic disturbance results in non-linear zircon arrays, which, however, can still be geologically interpreted if sufficient corroborating data are available.

GRANITIC AND METAMORPHIC STUDIES

This study has a number of facets, and an important part is to see whether the narrow 250 km-long belt of the Kalkadoon Granite (dated in northern parts at 1860 ± 25 m.y.) is a geochronologically integral unit, or whether evidence of older ages, supporting the hypothesis of an earlier-formed basement, can be found. New U-Pb zircon results from the Kalkadoon Granite (1860 ± 10 m.y.) in the far south, and Rb-Sr and U-Pb results from the Ewen Granite (1840 ± 50 m.y.) in the far north of the Inlier are consistent with earlier results and stratigraphic constraints. They suggest that the metamorphosed granitic rocks of the basement are part of the same magmatic suite. Biotite ages from the Ewen Granite, including those reported by McDougall & others (1965)*, are only 4 to 5 percent younger than the emplacement age of the system, whereas, in the Kalkadoon Granite and other bodies to the south, enhanced and prolonged metamorphic disturbances have resulted in many biotite ages of about 1400 m.y., about 20 percent younger than actual emplacement ages.

Further work was done on part of a younger granitic terrain, the Sybella Granite. In the last Annual Summary it was shown that high-level and deeper-level phases of the batholith have identical zircon crystallisation ages of close to 1670 m.y. The phase more recently studied, Sybella Microgranite, cannot be as satisfactorily dated, for the U-Pb data indicate that part of the zircon population is inherited from some pre-emplacement history. There is significant scatter about the U-Pb discordia trajectories of the two samples, and the apparent age of about 1710 m.y. is considered an artefact from a mixed suite of more than one age. This is the first time we have recognised inheritance in any of the Mount Isa igneous suites. Although it thwarts the primary purpose of the U-Pb work, as an adjunct to geochemical investigations, it will have important petrogenetic implications for these rocks.

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* Journal of the Geological Society of Australia, 12, 67-90.

U-Pb zircon work was begun on an isolated block of metamorphic rocks (Yaringa Metamorphics) in the western part of the Inlier. The fine-grained paragneiss being studied contains two recognised generations of zircon, one detrital, and the other developed in an amphibolite facies metamorphic episode. Preliminary isotopic data reveal the expected age differences between the two suites, but both ages are in excess of 2000 m.y. old. These Lower Proterozoic metamorphics therefore represent the oldest segment of crust yet recognised in the Mount Isa Inlier.

IGNEOUS ACTIVITY, METASOMATISM, AND URANIUM MINERALISATION IN THE MARY KATHLEEN SYNCLINE.

New information on the ages of alteration events in the vicinity of Mary Kathleen unfolded during the past year. Rb-Sr work was undertaken on thin rock slabs from banded calc-silicate granofelses, brecciated granofelses, and other altered Corella Formation calc-silicate skarns in different alteration envelopes within the Mary Kathleen Syncline. The mineralogy of these rocks formed as a result of high-temperature (500-600°C) metasomatic activity, which most workers regarded as a contact-aureole phenomenon associated with the emplacement of the nearby Burstall Granite and/or its rhyolitic apophyses. U-Pb zircon data, mentioned in last year's Annual Summary, showed that these intrusions are about 1730 to 1740 m.y. old.

The total-rock results on various types of altered granofelses and skarn rocks indicate that their alteration is a relatively juvenile event, taking place no earlier than 1200 m.y. ago in the Late Proterozoic. Alkali feldspar-rich bands from the granofelses are mildly to severely altered to fine-grained phyllosilicate minerals, and such assemblages reflect even younger open-system behaviour: Rb-Sr age measurements on two of them are 1060 m.y. and 1000 m.y., and their K-Ar ages (measured by courtesy of Dr Ian McDougall, RSES, ANU) are 470 m.y. and 550 m.y. Ignoring these as secondary (or ?tertiary) low-temperature effects, it is clear from the total-rock data that the metasomatism associated with the high-temperature mineralogy is about 500 million years younger than the Burstall Granite igneous events to which it has been attributed up until now. Therefore, it is unlikely that the alteration and mineralisation are genetically related to the Burstall Granite or its rhyolitic apophyses.

An apparent chaos of Rb-Sr ages measured some years ago on these rhyolites can now be satisfactorily understood in the light of this very young alteration event of about 1200 m.y. in the area. The rhyolite Rb-Sr data are reasonably consistent with the 1200 m.y. interpretation, and an exceptionally high indicated "initial" $^{87}Sr/^{86}Sr$ of about 0.80, is in fact an artefact from the alteration episode.

At present various samples of allanite-uraninite ore from the Mary Kathleen orebody are being studied to assist our understanding of the young metasomatic alteration. New reagents and different chemical techniques have been adopted to carry out the U-Pb work on these ore minerals. In addition, gamma-spectrometry to determine $^{226}Ra/^{238}U$ activity ratios shows about a 10% departure from secular equilibrium, in the sense of there being either an excess of Ra or loss of U from the ores. The minerals allanite, uraninite, apatite, and galena have been separated from three of the ore samples. Preliminary Pb isotopic analyses have been made on two galena fractions, but no adequate data interpretation can be made yet.

<u>COBAR AREA</u> by L.P. Black, M.J. Bower, D.B. Guy

Collaborative work, with R.A. Glen of the NSW Geological Survey, was continued in an attempt to date the main deformation in the Cobar Group. A further 13 total-rock samples were isotopically analysed for Rb and Sr. Unlike previous samples with layer-parallel schistosity, the new suite was characterised by a schistosity perpendicular to layering. A slightly but significantly younger age was recorded, but it is still considerably older than the presumed Carboniferous deformation. Three K-Ar ages (about 400 m.y.) on rocks with different feldspar: mica proportions are suprisingly concordant and still younger. However, these too are older than Carboniferous, when they would have been expected to be reset. The results from both isotopic systems are thus at variance with work from similar terrains. Further assessment of the data awaits the return of Glen from overseas when the possibility of a regional undetected unconformity in the Cobar area will be considered.

<u>ENDERBY LAND, ANTARCTICA</u> by L.P. Black, M.J. Bower, D.B. Guy, N.C. Hyett, T.K. Zapasnik

During the year work continued with colleagues P.R. James (structural geologist, University of Adelaide) and S.L. Harley (experimental petrologist, University of Tasmania). Eighty Rb-Sr and 42 U-Pb zircon analyses were made. These have led to the clarification of some problems but leave others still unresolved. Once again, study has been restricted to, and will continue for most of the coming year on, the cratonic rocks of the Napier Complex. Then, towards the end of 1982, emphasis will swing to the younger mobile belt rocks of the Rayner Complex. With the exception of some monazite analyses, Rb-Sr and conventional U-Pb zircon work on the Fyfe Hills and Field Islands areas are now essentially complete. This shows no support for the approximately 4000 m.y. age advanced by Soviet workers from Pb-Pb total-rock studies. Indeed, the original interpretation of the Soviet data can be shown to be invalid, as can a subsequent re-interpretaton of their data by American workers. It is clear that the history of this area extends well before the first granulite facies tectonothermal event at about 3100 m.y.

A small but distinct range of U-Pb zircon ages from about 2450 m.y. to 2490 m.y. has been obtained for the D_3 tectonothermal event. Future work is aimed at finding whether this is real and relates to the development of this event at different times in different areas, or to different rates of uplift. Alternatively, it might document the retention of a small variable component of inherited Pb within the zircon lattice.

An article on Proterozoic tholeiite dykes (with J.W. Sheraton) emphasising the role of mantle metasomatism was submitted for publication during the year. Rb-Sr isotopic data showed that crustal contamination was minimal in the early (2350 $\pm$ 50 m.y.) non-deformed dykes, especially the high-Mg suite. The data constrain metasomatism to immediately before the emplacement of these dykes. Metasomatism of the source region of the much younger group I tholeiites (1200 $\pm$ 200 m.y.) may have been contemporaneous with that of the high-Mg suite. An unrelated alkaline dyke at Priestly Peak was emplaced at 482 $\pm$ 3 m.y.

Black delivered talks on Enderby Land geochronology at the BMR Tuesday-morning series and at the University of Tasmania.

WESTERN TASMANIA by L.P. Black, M.J. Bower, D.B. Guy, T.K. Zapasnik

Rb-Sr and conventional U-Pb zircon work (12 analyses during the year) on this project have now been completed. The former produced ages which, through comparison with palaeontological constraints, can often be conclusively demonstrated to be up-dated by the Devonian Tabberaberran Orogeny. Indeed, none of the Rb-Sr isochrons can be guaranteed to have entirely escaped the effects of this orogeny. Conventional U-Pb zircon dating was plagued by the presence of zircon cores, which from isotopic arrays appear to contain considerable inherited Pb. Only one (or possibly two units) yielded a realistic age, though this was not particularly precise. It is hoped that through ion-microprobe examination it will be possible to exclude the core material from zircon analyses and hence obtain genuine magmatic ages for these rocks. Such ages have important ramifications for the timing of extensive mineralisation in the area and would also provide isotopic fixes for this part of the (mostly Cambrian) time scale.

Because of the isotopic perturbations, only broad chronological conclusions can be drawn from the present data. They are more useful for documenting the complex processes which can affect igneous rocks in such a terrain. A preliminary manuscript has been prepared with co-workers K.D. Corbett and G.R. Green of the Tasmanian Department of Mines.

TENNANT CREEK BLOCK by L.P. Black, M.J. Bower, D.B. Guy, T.K. Zapasnik

Previous Rb-Sr work was unsuccessful in defining the depositional age of the Warramunga Group. Consequently, a U-Pb zircon study was initiated on the stratigraphically concordant Bernborough Volcanics, for which an age between 1820 m.y. and 1850 m.y. was obtained. If a previously postulated correlation is correct, Division II rocks of the Arunta Block are also this age. From the zircon age it can be deduced that the amphibolite-facies rocks in the Tennant Creek area are basement to - not merely higher-grade equivalents of - the Warramunga Group. The study will shortly be reported in the BMR Journal.

Four U-Pb zircon analyses were made on the Tennant Creek and Cabbage Gum Granites. The data are as yet insufficient for realistic interpretation.

GEORGETOWN INLIER by L.P. Black, M.J. Bower, N.C. Hyett, T.K. Zapasnik

Forty-six complete Rb-Sr analyses were made during the year for essentially two different projects. The first of these involves determining the age of Proterozoic to mid-Palaeozoic granitoids within the inlier. This work has been continuing for several years. Recent analyses have been on samples collected by R.D. Holmes (ANU Geology Dept) for which better controlled geochemical constraints are available than for those collected by BMR-GSQ geologists.

The second Rb-Sr project involves joint work with T.H. Bell (James Cook University), who is providing the structural control necessary for the interpretation of Rb-Sr isochrons in tectonothermally complex terrains. Isotopic data indicate that the Judea beds and Lucky Creek Formation were updated in the Siluro-Devonian, though it has yet to be finalised during which event of their tectonothermal history that this occurred. It is hoped that a manuscript will be prepared during Bells' 3-month visit to the ANU this summer.

U-Pb zircon dating was completed on 11 zircon separates from two metamorphic units within the inlier. Those from the Einasleigh Metamorphics near Percyville yield an age (about 1570 m.y.) in agreement with that derived by Rb-Sr analysis at the same time for D_1 deformation-metamorphism. Clearly detrital zircon from the Robertson River Metamorphics yields a considerably older age which, because of marked discordance, cannot be determined precisely.

Two weeks were spent in the field collecting granitoid samples for future U-Pb zircon analyses. Units collected were the White Springs Granodiorite, Forsayth Granite, Lighthouse Granite, Dido Granodiorite, Mistletoe Granite, Dumbano Granite, Forest Home Granodiorite, and Esmeralda Granite.

HERBERTON-MOUNT GARNET AREA by L.P. Black

Seven Rb-Sr analyses were made to complete a study of the Nychum Volcanics. The data were jointly written up with geochemical evidence of J.C. Bailey (Copenhagen University) and W.R. Morgan (W.A.I.T.) and submitted for external publication. Isotopic data indicate that the volcanics are complex and contain unrelated magma types. Most of the felsic units probably crystallised at about 270 m.y., and possibly are lateral equivalents of the nearby but much more extensive Featherbed Volcanics.

Sm-Nd STUDY by L.P. Black

Fifteen Sm-Nd analyses have been made to determine initiation ages of the Tennant Creek Block, Georgetown Inlier, and the Arunta Block. The technique has advantages over Rb-Sr and U-Pb zircon dating systems in that it is less easily reset by non-magmatic events. Additional analyses are required before an estimate can be made of the approximation to bulk-earth conditions of the Precambrian upper mantle under these areas.

MISCELLANEOUS ACTIVITES

PRECAMBRIAN REGIONAL GEOLOGY by K.A. Plumb.

During the year, the comprehensive review paper by Plumb, Derrick, Needham, & Shaw - "The Proterozoic of northern Australia" - was finally published by Elsevier in their book "Precambrian of the Southern Hemisphere" (D.R. Hunter, Editor), and papers by Plumb on the Upper Proterozoic tillites of the Kimberley -Victoria region and the Duchess area were published by Cambridge University Press in "Earth's Pre-Pleistocene Glacial Record" (M.J. Hambrey & W.B. Harland, Editors).

This completes the publication of major reviews of north Australian Precambrian geology prepared in recent years.

<u>EXPANDING EARTH HYPOTHESIS IN THE LIGHT OF PROTEROZOIC-PHANEROZOIC TECTONIC COMPARISONS</u> by K.A. Plumb.

Two major factors figure prominently in the expanding Earth debate:
1) the evolution of the Alpine-Himalaya chain and its forbear, Tethys;
2) comparison or similarities between the tectonic processes operative in Proterozoic and modern mobile belts. As a contribution to this debate, Plumb presented a paper - "Himalayas and Tibet Plateau - Vertical Versus Horizontal Tectonics - and Possible Proterozoic Analogues" - at Professor Carey's "Expanding Earth Symposium" in Sydney, during February, 1981. The final paper for publication is nearing completion.

In essence it is concluded that geological arguments for or against an expanding Earth are inconclusive. Although geological data are not incompatible with an expanding Earth, there is no geological requirement, from the regions studied, that a smaller-radius Earth existed in the past. The expanding Earth hypothesis must eventually rely on direct physical measurement of changes in Earth radius, and on an adequate physical theory that allows or explains an expansion of Earth radius through time.

Analysis of recent geological and geophysical data from Tibet and the Himalayas leads to the conclusion that plate tectonics, subduction, compression, and crustal shortening have been the dominant processes involved in the evolution and eventual closing of Tethys. Carey's alternative models, to explain orogenesis on an expanding Earth, are untenable. Although it is demonstrated that plate tectonics, etc. need not be incompatible with an expanding Earth, equally these same processes may, on a constant-radius Earth, adequately explain all the geological and biological anomalies which are commonly considered as demanding an expanding Earth.

The Proterozoic mobile belt of central Australia reveals tectonic similarities with Tibet and the Himalayas. Fundamental tectonic processes might not have changed significantly through time. Central Australia comprises a number of distinctive tectonic belts, separated by major thrusts. All the rocks presently exposed are ensialic, but so are most of the rocks now exposed in

Tibet and the Himalayas. Almost all of the former Tethys ocean has been subducted and ensialic underthrusting is presently occurring beneath the Himalayas. But once again, although the absence of known Proterozoic oceanic crust can thereby be rationalised on a present-radius Earth, equally it is not possible to differentiate between the Tibetan collision-reactiviation model of Dewey and Burke and the ensialic subduction or underthrusting models of Alfred Kroner.

Thus, it is concluded that the plate tectonic model allows all biological observations to be rationalised on a constant-radius Earth, while recognising equally that plate tectonics or related processes are not incompatible with an expanding Earth. While a smaller-radius Precambrian Earth, and a consequent small rate of expansion, may be an attractive explanation of many Proterozoic geological anomalies, the very large rates (up to 40%) of expansion, which some authors propose since Triassic, seem unlikely.

INTERNATIONAL CONFERENCES AND OVERSEAS VISITS

FOURTH WORKSHOP ON STATUS, PROBLEMS AND PROGRAMMES IN THE CUDDAPAH BASIN, INDIA.

K.A. Plumb, together with Dr B. Daily (University of Adelaide) and Mr D. Clark (CSIRO), visited India during January, 1981, to attend the "Fourth Workshop on Status, Problems and Programmes in the Cuddapah Basin" and to undertake a field trip to the Cuddapah Basin with a view to comparing it with Proterozoic basins in Australia.

The visit was funded through the India/Australia Science and Technology Agreement.

WORKSHOP

The workshop was one of a series conducted by the Institute of Indian Peninsular Geology at the National Geophysical Research Institute (NGRI), Hyderabad, to review progress of earth-science research in Peninsular India, particularly the Cuddapah Basin.

Plumb presented a paper entitled "Tectonic Setting of the Carpentarian and Adelaidean Intracratonic Basins of Australia". Daily and Clark presented reviews of the geology and the geophysics, respectively, of the Adelaide Geosyncline. The papers are being published by the Institute of Indian Peninsular Geology.

CUDDAPAH BASIN

The Cuddapah Basin is a large mildly to moderately deformed epicontinental Proterozoic platform cover, overlying Archaean basement of the Peninsular Shield. Geophysics indicates a maximum thickness, at any one point, of about 6 km.

Stratigraphy

Three major sequences are separated by unconformities. The lowest sequence (7500 m thick) comprises stromatolitic dolomites (Papaghni Group), disconformably overlain by alternating arenite-lutites (Chitravati Group). This is unconformably overlain by 2500 m of interbedded shale, phyllite, quartzite, and dolomite (Nallamalai Group). Finally, 500 m of flat-lying sandstone, shale, and limestone (Kurnool Group) is unconformable on both earlier sequences.

Age

The Papaghini Group is older than 1550 m.y. and possibly as old as 1700 m.y. The Nallamalai Group is constrained between 1400-1200 m.y. The Kurnool Group is younger than 980 m.y. and probably older than 800 m.y.

Tectonic setting

The Cuddapah Basin comprises two distinct sub-basins, which reflect two major tectonic zones in the underlying basement. The "western sub-basin" contains gently-dipping Chitravati and Papaghini Groups, overlying a cratonic block of Archaean Peninsular Gneiss. The "eastern sub-basin" contains tightly-folded and overthrust Nallamalai Group rocks above the "Eastern Ghats" - the polymetamorphic charnockitic mobile belt of India. The boundary between the sub-basins is an overthrust belt, corresponding exactly to the tectonic boundary between the basement belts.

Mineral deposits

Seventy-five million tonnes of bedded barytes have been proved in the Nallamalai Group at Mangampeta. Small vein and fracture deposits are common.

Prior to the discoveries in South Africa, Penisular India was the major diamond producer of the world. Kimberlite pipes have been established as about 1200 m.y. old, and diamond-bearing conglomerates in the Kurnool Group were a major resource until mined out a couple of centuries ago.

Numerous small deposits of lead-zinc, copper, and asbestos are known.

Comparison with Australia

As a composite basin, the Cuddapah Basin is unique and has no direct analogues in Australia.

The older succession (Papaghini/Chitravati Groups) resembles the McArthur Basin of northern Australia in age, rock types, stratigraphic succession, and tectonic setting. The Kurnool Group is of similar age to the older parts of the Adelaide Geosyncline, but has no particular stratigraphic analogies; particularly striking is the absence of tillites.

The tectonic relationship of a stable platform passing eastwards into a mobile belt might be likened to the Stuart Shelf-Adelaide Geosyncline, although in the Australian example the sequences are of the same age, rather than of different ages as in India. More valid tectonic comparisons might be made with the Officer-Amadeus-Georgina Basins of central Australia.

OVERSEAS VISIT, UNITED STATES OF AMERICA - R.J. TINGEY 6-16 MAY 1981

Tingey visited the United States in May 1981 primarily to attend the final planning meeting for the International Geological Expedition that will visit north Victoria Land, Antarctica in 1981-82. The meeting was held at the Geology Department, Arizona State University at Tempe, near Phoenix, Arizona, the home institution of the scientific director of the expedition Dr Ed Stump, and was attended by participating scientists from all over the United States and representatives from New Zealand and West Germany as well as senior officers of the National Science Foundation. Tingey represented Australian interests in the Expedition. The meeting was mainly concerned with the allocation of logistic resources to various field parties and with collaboration with the West German Expedition due to operate in the region in 1981/82. Confusion over who from Australia was to participate was also dispelled following discussions with Dr Stump.

After the meeting, Tingey joined a field tour organised by the Geology Department, Arizona State University, which travelled north from Phoenix to the Grand Canyon via Meteor Crater, east of Flagstaff, and the San Francisco Peaks area just north of Flagstaff, where a bimodal volcanic complex which was active in historical times is well displayed.

After the excursion, Tingey flew to San Jose in the north of California and visited the Menlo Park offices of the United States Geological Survey, specifically to visit Dr Arthur Ford, who has played a leading role in USGS investigation of the Dufek Massif in Antarctica. Tingey gave a lecture on Australian geological work in Antarctica. He also visited Mr John Bain, from BMR, who is spending a year at Menlo Park on an overseas exchange arrangement.

PROTEROZOIC SYMPOSIUM, UNIVERSITY OF WISCONSIN, MADISON by A.Y. Glikson

An invitiation was received by the organisers of this symposium, with travel expenses covered, to present a paper on the question of an early Precambrian Earth radius. The symposium was held during 18-21 May, 1981, at the University of Wisconsin, Madison, and was accompanied by a field excursion to the Lake Superior region, where Keweenawan volcanics, Early Proterozoic sediments, and Archaean greenstones were examined. The paper presented at the symposium was entitled - "Geochemical, isotopic and palaeomagnetic tests of Precambrian sial/sima patterns and early Earth radii". Geochemical parameters and Rb/Sr, Sm/Nd, and Pb isotopic indices for Precambrian acid igneous rocks suggest a largely ensialic crustal record for 2500-1000 m.y., though simatic regimes may have existed in some areas, i.e., southwest USA and Fennoscandia. Sm/Nd isotopic data indicate major mantle differentiation events about 2700-2600 m.y. and about 1000 m.y., but rarely in-between. The scarcity of oceanic crustal signatures in the geological record of this era, limits on volume and thickness of Proterozoic sial, and palaeomagnetic APWP (apparent polar wander path) evidence of present-day angular distances between Early Proterozoic shields render the data difficult to reconcile with modern Earth surface dimensions. The evidence indicates derivation of the bulk of Archaean magmas from basic precursors and the bulk of Proterozoic magmas from differentiated sialic crust. The significance of initial Sr^{87}/Sr^{86} ratios (Ri) to source composition is examined in conjunction with large-ion lithophile (LIL) element data, e.g., K/Na, Rb/Sr, U, Th. These values are higher in Proterozoic than Archaean acid igneous rocks, indicating a predominantly eutectic nature of Proterozoic silicic melt products of ensialic anatexis, and a prevalence of two-stage mantle melting processes in the Archaean. K/Na, rare-earth element (REE), and Sr^{87}/Sr^{86} data for Proterozoic sediments enable an identification of differentiated igneous/metamorphic K-rich granitic source terrains, unlike the Archaean tonalite-greenstone crust. From about 1000 m.y., progressive development of simatic crust is indicated by an increasing abundance of ophiolites, low Ri and low LIL acid igneous rocks, and divergent APWPs. Opening of oceanic crustal gaps such as long pan-African belts may signify major crustal dilatation. Possibly a similar mechanism may explain major Archaean greenstone-tonalite phases as manifestations of tensional episodes. As it is demonstrable from the Proterozoic record that during 2500-1000 m.y. about 1/4 of the Earth's crust was occupied by sialic crust of at least continental thickness, a question arises with regard to the nature of the other 3/4 of the Earth's crust. Five alternative models are considered: (1) Global sial of continental thickness; (2) a thin global sial; (3) dispersed sial and sima plates; (4) hemisphere-size simatic regime; (5) global sialic crust on a smaller Earth. The apparent inability of models 1, 2, 3 and 4 to account for the nature of about three-fourths of the Earth's crust during some 1500 million years inevitably directs attention toward model (5). Objections to and constraints on the amount of expansion were considered.

IAVCEI SYMPOSIUM ON ARC VOLCANISM, TOKYO-HAKONE, JAPAN by R.W. Johnson.

Johnson attended the 1981 'Arc volcanism' symposium which was held in Japan between 28 August and 9 September 1981. The symposium was organised by the Volcanological Society of Japan and the International Association of Volcanology and Chemistry of the Earth's Interior. Johnson's visit was sponsored in part by UNESCO, who ran a special seminar entitled 'Volcanic hazard appraisal in the Circum-Pacific area'.

Johnson was a participant in a pre-symposium excursion to southwestern Hokkaido where visits were made to Kuttara, Toya, and Shikotsu calderas. Highlights included examinations of the 1943-45 Showa-Shinzan dome, the volcanological observatory near Toya-Spa, and the effects of the 1977-78 eruption of Usu-Shinzan.

Scientific sessions of the symposium were held in Tokyo and Hakone. There were about 470 registrants. Meetings had to be run in parallel, and many papers could not be presented orally as there were too many submitted. Johnson was co-author of eight papers, mainly on Papua New Guinea volcanology, petrology, and geochemistry, and he led a discussion during the UNESCO seminar on the proposal for a Western Pacific volcanological institute.

Johnson also participated in a post-symposium excursion to southern Kyushu. The excursion included examinations of Kagoshima caldera, the Ito pyroclastic-flow deposit, the volcanoes of Kirishima, and Aso caldera, as well as visits to the volcanological observatories at Sakurajima and Kirishima volcanoes. A spectacular highlight was a vulcanian eruption from Sakurajima and observation of the effects of ash fallout on a nearby village.

SASKATCHEWAN URANIUM GEOLOGY SYMPOSIUM, SASKATOON, CANADA, AND VISITS TO CANADIAN AND US URANIUM MINING DISTRICTS by R.S. Needham.

The Conference was organised under the auspices of the Canadian Institute of Mining and Metallurgy and the (US) Society of Economic Geologists. Twenty-three papers were presented, twelve poster displays mounted, and an extensive core display featuring material from most of the major uranium deposits in Saskatchewan was available for inspection. A two-day excursion was repeated before and after the technical sessions.

The main objective was to present information on the uranium deposits of the Athabasca Basin and on pertinent aspects of the regional geology. Although the general setting of these deposits is similar, alteration has affected the deposits in different ways. In addition, the detailed relationship between mineralisation and the Athabasca Sandstone is not consistent, and therefore leads to markedly divergent schools of ore-genesis theory. Some company geologists emphasised the importance of the Wollaston Fold Belt metamorphics, whereas several government/academic geologists saw a relationship between uranium mineralisation and the distribution of basal facies within the Athabasca Sandstone.

Uranium deposits of four other areas were described, namely the Keewatin district of the Northwest Territories, Deer Lake Basin in Newfoundland, central Europe, and the Alligator Rivers region in Australia. The Australian papers described post-Kombolgie alteration at Jabiluka, progress of USGS study of the Ranger orebodies, and, presented by Needham, distribution and controls of uranium mineralisation. One poster display also indicated progress of the USGS study on the Jabiluka deposits.

The excursion visited uranium deposits at Beaver Lodge, Cluff Lake, and Key Lake.

After the symposium and excursion, Needham toured the Aphebian geology of the Beaverlodge region and visited the Rabbit Lake uranium deposit under the guidance of the Saskatchewan Geological Survey. He was then guided over the Sudbury and Elliot Lake mining districts by the Ontario Department of National Resources; the Schwartzwald mine and nearby prospects by the Colorado School of Mines; the Henderson molybdenum mine (Colorado) and uranium mines in the Shirley and Powder River Basins of Wyoming by the USGS Uranium and Thorium

Branch; and the King Solomon Uranium mine of the Uravan district of Colorado and the Johnny M uranium mine of the Grants Mineral Belt of New Mexico, by the US Department of Energy.

Lectures on the Alligator Rivers Uranium Field or the Pine Creek Geosyncline were presented to the Saskatchewan Geological Survey in Uranium City, to the Ontario Department of National Resources in Sudbury and Toronto, to the Colorado School of Mines in Denver, and to the Department of Energy in Grand Junction, Colorado.

All travel and symposium costs for R.S. Needham were met by a grant from the Society of Economic Geologist Foundation; G.R. Ewers of BMR was also able to attend the conference following a grant of funds from the Organising Committee of the International Uranium Symposium on the Pine Creek Geosyncline.

OVERSEAS VISITS TO CHINA by H.L. Davies & R.W. Page.

H.L. Davies visted Hainan Island, Guangzhou (Canton), and Beijing (Peking), in September 1981, as a member of a Department of Trade and Resources Mission. The object of the mission was to assess opportunities for Australian investment or co-operation in the development of resources on Hainan Island and particularly in the development of mineral and energy resources. Upon completion of the mission Davies drafted a report which reviewed the geology and known mineral and energy resources. He concluded that, while there appeared to be no immediate development opportunities, the island was clearly prospective for a variety of types of mineralisation, including mineral sands (some production), tin-tantalum in granite, porphyry copper and molybdenum, and stratiform base-metal sulphides, and these present attractive exploration targets, provided that satisfactory terms and conditions could be negotiated. During the visit to Guangzhou the opportunity was taken to present an illustrated talk on Papua New Guinea geology to an audience of about 75 earth scientists at the headquarters of the Guangdong Bureau of Geology.

Dr R.W. Page was taken on duty to accept invitations from the Chinese Academy of Geological Sciences (Ministry of Geology) and the Guiyang Institute of Geochemistry (Academica Sinica). In addition to delivering 5 lectures on aspects of Australian geochronology, and leading 3 workshops on technical matters, the principal accomplishments of the visit were:

(i) in company with Chinese field geologists and geochronologists, assess the field evidence and relationships in a metamorphosed late-Archaean sequence in west Hebei and Shenxi Provinces. This helped to resolve a number of problems of terminology and interpretation of isotopic data. It enabled the near-completion of a joint paper on the geochronology of this metamorphic terrain.

(ii) in company with Chinese geologists, examine the Sinian (late Precambrian) and early Cambrian sequence in the East Yangtze Gorges area, Hubei Province. This visit and associated discussions led to further progress on a second joint paper with the Chinese, on the age of the Precambrian - Cambrian boundary in central China.

(iii) inspection of seven laboratories of isotope geology. Five of these were in Peking, one in Yichang (central south China), and one in Guiyang (southwest China). In these visits various degrees of advice and assistance were tendered, especially to those institutes considering the setting up of modern zircon dating facilities.

CONFERENCES ATTENDED

The following conferences were attended by members of the Section:

Australasian Sedimentologist Group 1980 Conference, Canberra, December: D. Wyborn.

Fourth Workshop on Status, Problems and Programmes in the Cuddapah Basin, India, January: K.A. Plumb

Expanding Earth Symposium, Sydney, February: A.Y. Glikson, K.A. Plumb

COGS/AMSTAC Workshop on Australian and Ocean Drilling, Canberra, March: R.W. Johnson

Proterozoic Symposium, Madison, USA, May: A.Y. Glikson

Fifth Australian Geological Convention, Perth, August: I.H. Crick, B.S. Oversby, H.L. Davies

International Conference on Deformation Processes in Tectonics, Alice Springs ,August: A.J. Stewart, R.D. Shaw, H.L. Davies, L.A. Offe, R.G. Warren.

Sixth Australian Symposium on Analytical Chemistry, Canberra, August: B.I. Cruikshank

GANOVEX Workshop, Hannover, Germany, September: D. Wyborn

IAVCEI Symposium on Arc Volcanism, Tokyo-Hakone, Japan, August/September: R.W. Johnson.

Volcanic Hazards Appraisal in the Circum-Pacific, Hakone, September: R.W. Johnson

Saskatchewan Uranium Geology Symposium, Saskatoon, Canada, September: R.S. Needham, G.R. Ewers

Symposium on Mount Isa Geology, Mount Isa, September: D.H. Blake, R.W. Page, L.A.I. Wyborn, K.R. Walker.

Granite Workshop, Townsville, September: B.S. Oversby

GSWA Excursion to Sandstone and Youanmi Sheet areas, October: A.J. Stewart.

GEOLOGICAL SERVICES SECTION

Head: E.K. Carter

ENGINEERING GEOLOGY AND HYDROGEOLOGY

STAFF: E.G. Wilson (retired 12 August), G. Jacobson, G.A.M. Henderson, J.R. Kellett, W.R. Evans, G. Sparksman, K. Reine, A.W. Schuett,

The group continued its functions of:

1. Geological mapping, engineering geology, and hydrogeology in the Australian Capital Territory and other Commonwealth territories.

2. Specialist advice to Commonwealth agencies with respect to engineering geology and hydrogeology. Advice was provided to, or collaborative work was undertaken with, the following agencies:

    Australian Atomic Energy Commission
    Australian Development Assistance Bureau
    Australian Water Resources Council
    CSIRO Division of Land Use Research
    Department of Administrative Services
    Department of the Capital Territory
    Department of Housing and Construction
    National Capital Development Commission
    Parliament House Construction Authority
    Pipeline Authority

3. "Regolith Program" research, utilising the group's skills in geomorphological, soils and hydrogeological investigation techniques.

E.G. Wilson retired on 12 August after nearly 15 years service with BMR, spanning 22 years. During the year under review he was engaged in a study of overseas developments in nuclear waste disposal techniques in geological environments, and in the completion of a report on the engineering geology of a Melbourne tunnel. He also served as the BMR representative on the Groundwater Committee of the Australian Water Resources Council, and as Secretary of the organising committee of the 1982 AWRC conference on fractured-rock aquifers.

G. Jacobson represented BMR on the Water Quality Subcommittee of the Interdepartmental Committee on Environment Quality in the ACT; on the organising committee of the 1983 AWRC international conference on "Groundwater and Man"; and on two technical advisory panels of the Australian Development Assistance Bureau. He participated in the work of an in-house committee, under the convenership of the Section Head, set up to advise the Director on the role of BMR in water research and assessment.

Carter and Jacobson contributed to a review of the Lake Way uranium deposit (WA) draft environmental impact statement.

Locations of some of the group's hydrogeological investigations in southeast Australia are shown in Figure G1.

CAINOZOIC WEATHERING AND SALINITY

by

W.R. Evans

A joint study is being undertaken with the Division of Land Use Research, CSIRO, into the possible origins of highly saline groundwater in the Begargo Creek catchment near Lake Cargelligo (NSW).

During the 1981 field season, drillhole LC3 was drilled to 115 m and completed as a water-bore, and in the northeast part of the catchment the geomorphology was studied in detail. From this work a Cainozoic stratigraphy has been constructed (Fig. G2).

Tertiary volcanic and sedimentary units

The oldest outcropping Cainozoic material is represented by the sediments of the Gibsonvale-Kikoira Deep Lead tin mine. These comprise alluvial deposits of sand-gravel-boulder mix dominated by quartzose clasts. The deep lead varies between 5.3 and 26 m thick and is 6.4 km long by up to 250 m wide. The sediments have been lateritised, and are tentatively dated as late Oligocene. The interval 23.5 m to 25.4 m in BMR drillhole LC1, a truncated goethite gravel, is correlated with the deep lead.

Several flows of olivine leucitite at Begargo Hill overlie a pumice layer which grades down into gravel and silcrete. The leucitite has been dated at 10.2 to 14.0 m.y. No lateritisation has taken place. This implies that the laterite weathering event took place sometime between late Oligocene and late Miocene.

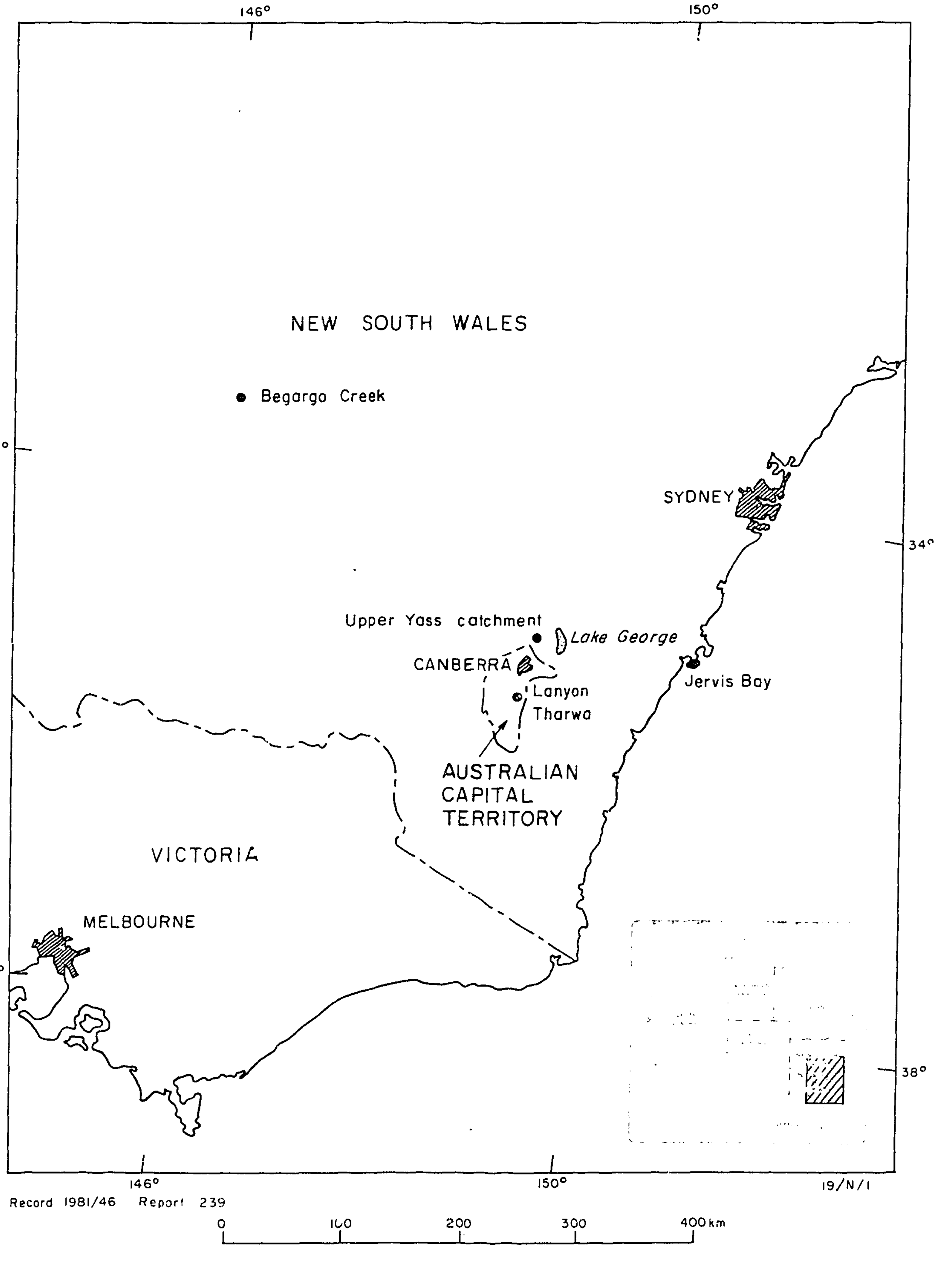

Fig. G1 Location map, hydrogeological investigations 1981

Quaternary Pedoderms

Three Quaternary pedoderms have been defined.

Yelkin Pedoderm. The oldest of the three, it consists of a lower coarse-grained alluvial unit and an upper fine-grained alluvial-aeolian unit. Pedogenesis has produced a grey plastic B-horizon clay; the peds are angular and about 5 cm across. A large-scale mottling pattern of red-brown, green, yellow-brown, and grey is common. Subhorizontal bedded carbonates and carbonated worm-burrow infillings occur within the upper unit.

An extensive calcreted bedrock terrace is included as a variant in this pedoderm, as there is a close field relationship between the two and the bedrock terrace shows the typical mottling.

Boorblan Pedoderm. This unit consists of an accumulation of braided stream-alluvial fan material, including coarse channel and finer overbank deposits. Pedogenesis has produced large blocky 10 x 10 x 10 cm peds in podzolic and earth profiles which have distinctive organocutans on ped faces. Subsolum weathering patterns show red with small-scale mottling, and in some places modify the underlying Yelkin upper unit. Carbonate nodules are present.

This pedoderm forms the main dune system around Lake Brewster, and also large low-amplitude longitudinal dunes on the main valley floor.

Begargo Pedoderm. This unit represents the youngest deposit. It is characterised by thick unbraided channel gravels and thinner overbank deposits. Pedogenesis has produced grey to red prairie soils and earths. There is no subsolum weathering. Carbonate nodules are present.

The three pedoderms are probably late Pleistocene to Recent.

Chemistry

X-ray diffraction patterns indicate that the carbonates of the surficial material are high in magnesium. Soil extracts show high values for magnesium, calcium, sodium, and chloride.

Analyses of groundwater from the fractured-rock aquifer show water dominated by Na and Cl and also high in Mg and SO_4. Compared with sea water, the groundwater is enriched in HCO_3 and depleted in Mg and Ca.

During the Yelkin phase, sand, silt, and soluble salts were blown into the catchment from the Murray Basin, to be incorporated as the upper Yelkin unit. This was then leached under hot wet conditions, leaving Mg and Ca locked into calcretes and pedogenic carbonates while the more soluble salts moved into

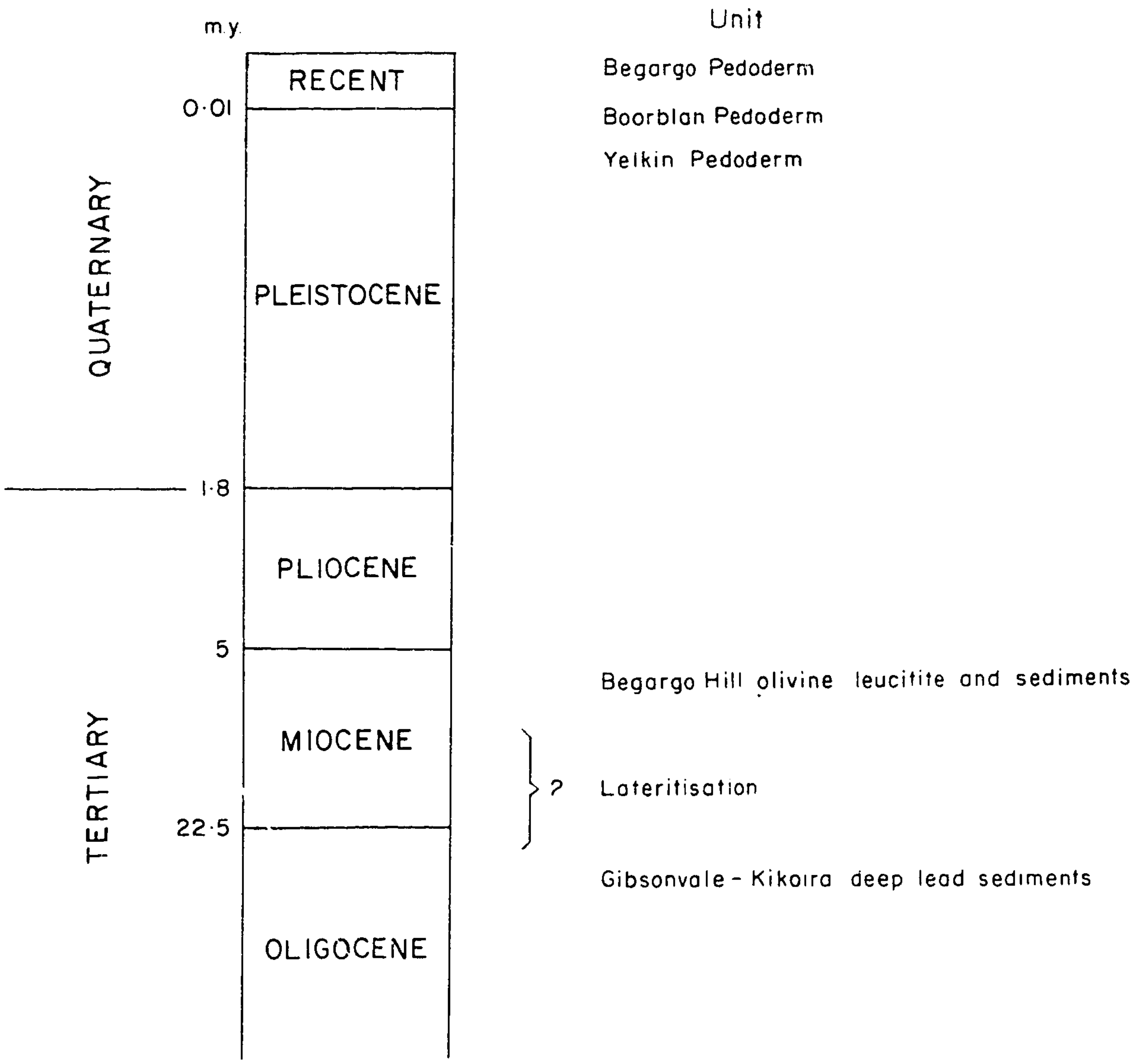

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Fig. G2 Cainozoic stratigraphy, Begargo Creek catchment, New South Wales the regional groundwater or were trapped in areas of low permeability. Degradation during Boorblan and Begargo phases and subsequent redeposition produced the complex association of soluble salts seen at the present time.

GROUNDWATER IN OCEANIC ISLANDS - FOREIGN AID PROJECTS

by

G. Jacobson

Under Australian bilateral foreign aid programs, BMR investigated the water supply of three islands in the Pacific Ocean. The locations are shown in Figure G3.

Hydrogeology of a limestone coast, Espiritu Santo, Vanuatu

Under its bilateral aid program to Vanuatu, the Australian Government is about to construct a secondary school on the island of Espiritu Santo. Engineers from the Department of Housing and Construction sought geological advice from BMR about the most suitable water supply for the school. A brief field investigation showed that the school site is on a limestone coast (Fig. G4) with no suitable surface water except for two brackish springs. The drinking water supply will therefore have to come from bores. The prognosis for a bore water supply is good; suitable bore sites have been selected; and a local drilling capability has been confirmed.

Groundwater on a raised coral atoll - Niue Island

Field investigations of the hydrogeology of Niue Island in the South Pacific Ocean were undertaken in 1979 and reported on in the BMR Journal in 1980. The Australian Development Assistance Bureau is now funding a water supply "aid package" for Niue including a new drilling rig, pumps, and the cost of 12 water-bores. BMR advice was given in 1981 on the purchase of appropriate equipment.

Hydrogeology of Tarawa Atoll, Kiribati

An investigation of the hydrogeology of Tarawa Atoll, Kiribati, was undertaken late in 1980 and reported on in 1981. Assistance was given to the Department of Housing and Construction who were briefed by the Australian

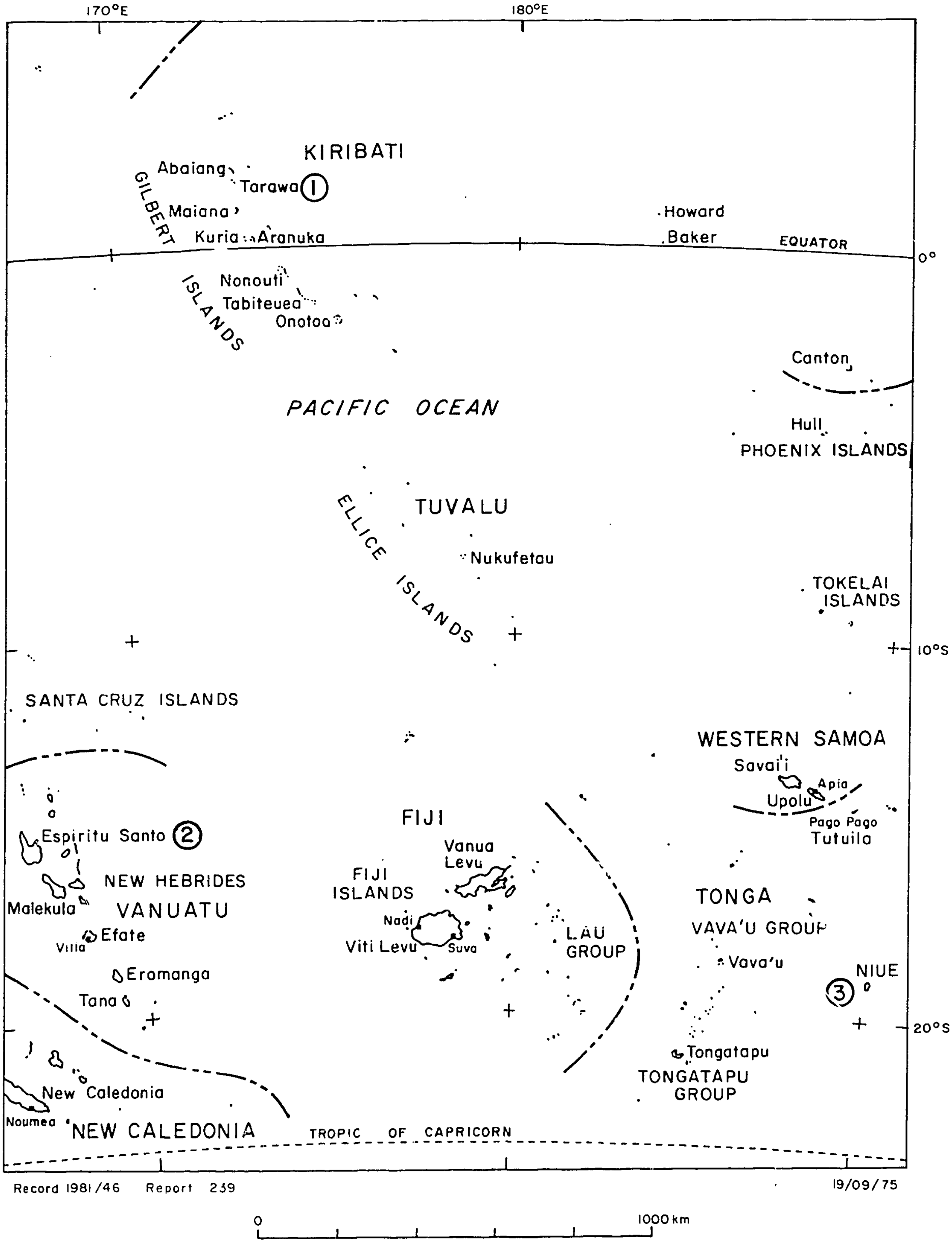

Fig. G3 Groundwater investigations of Pacific islands; (1) Tarawa, (2) Espiritu Santo, (3) Niue

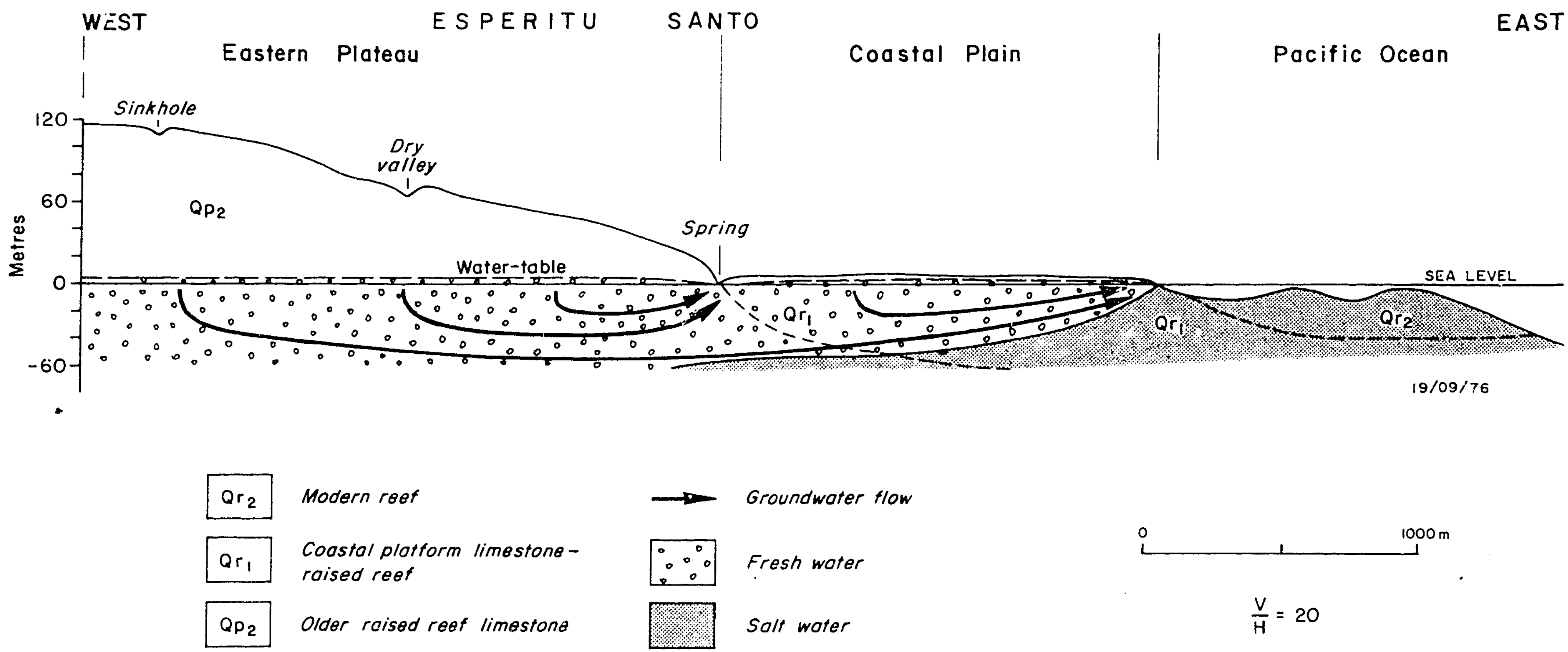

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Fig.G4 Hydrogeology of a limestone coast, Esperitu Santo, Vanuatu

Development Assistance Bureau to design an improved water supply for the atoll. Tarawa is one of the sixteen atolls which form the Gilbert Islands, and is the administrative centre of the Republic of Kiribati.

Resistivity surveys were carried out on several of the component islands of the atoll to define the configuration of the freshwater lenses. Boreholes were constructed to investigate the geology and provide water quality monitoring points. The bores intersected coral sand overlying buried coral reef, with a limestone sequence below 15-20 m. An aquifer test in one of the boreholes indicated high permeability in the limestone.

Several of the freshwater lenses appear capable of further development, and the total safe yield of the aquifers is probably more than 12 l/s. In particular, the lens on the northernmost island, Buariki, is up to 29 m thick and forms a substantial reserve of freshwater. A modelling study is being undertaken by colleagues in the Department of Housing and Construction in order to determine an appropriate long-term water management plan.

Samples of coral from drillholes have been submitted for carbon dating in order to elucidate the geological evolution of the atoll.

GROUNDWATER SEEPAGE AND THE WATER BALANCE OF LAKE WINDERMERE, JERVIS BAY

by

G. Jacobson

A long-term study of groundwater seepage and the water balance of Lake Windermere was completed and a report prepared. The lake is important as a water supply for the Commonwealth Territory of Jervis Bay.

A 20-year record of lake levels and a 10-year record of groundwater levels were analysed. There are considerable fluctuations in water-levels as a result of climatic variations (Fig. G5). A pump test was conducted to ascertain the hydraulic parameters of the Quaternary sand surrounding the lake. A computer program was then developed for the lake water balance. Results indicate that there is considerable groundwater seepage from the lake when the lake level is high. In fact, groundwater seepage is the most significant component (84 percent) of the outflow from the lake.

There are large resources of good quality groundwater which could supplement lake water should the latter prove inadequate for the Territory water supply.

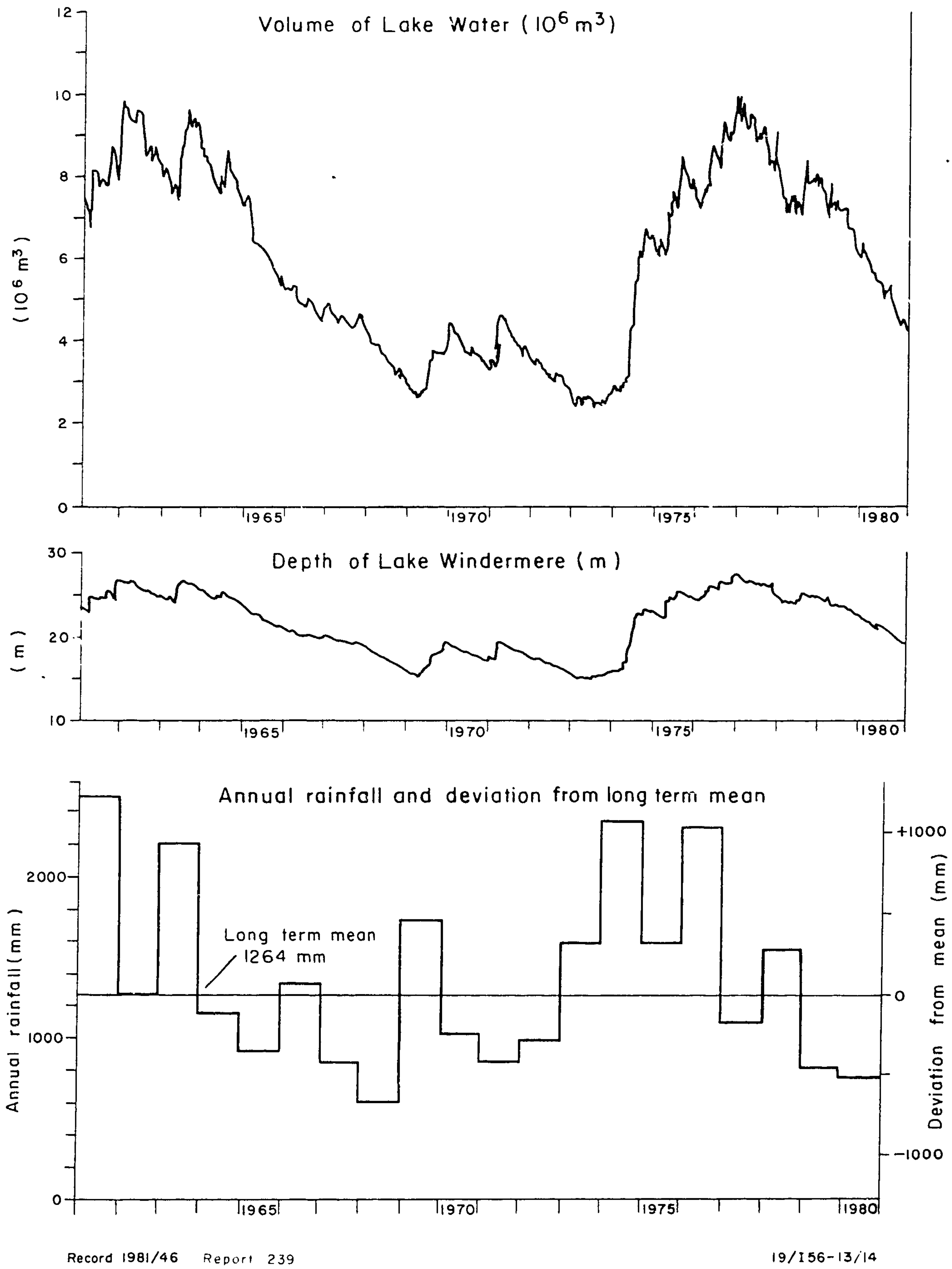

Fig. G5 Fluctuations in depth and volume of Lake Windermere; and annual rainfall at Jervis Bay, 1961-80

HYDROGEOLOGICAL STUDIES - ACT AND ENVIRONS

by

W.R. Evans, G. Jacobson & J.R. Kellett

Bore water supplies

Several inspections of potential water-bore sites in the ACT were made for government departments and institutions. Groundwater is a valuable resource for rural water supplies or, in the urban area, for irrigation of parkland. Sites where the construction of borefields was recommended included Gold Creek homestead, Canberra racecourse, and the Red Hill golfcourse.

Groundwater pollution investigations

Surveillance continued of six sites in the ACT which are affected by, or have the potential for, groundwater pollution.

Two sites in central Canberra are affected by petrol pollution from underground installations. At one of these sites a recovery system skims petrol from the water-table at the centre of a cone of depression induced by pumping. At the other site, no remedial action has yet been taken.

Three sanitary landfill sites were monitored. At two of these, additional monitoring bores were constructed by contractors. A paper on geological factors affecting landfill sites was published in the BMR Journal.

Additional bores were also constructed at an industrial estate at Hume, ACT, to monitor industrial effluent from a proposed timber treatment plant.

Groundwater seepage problems affecting urban development

Assessments were made of several groundwater seepage problems which affect existing or proposed urban development in the ACT. Springs along the Canberra-Dalton gas pipeline were inspected for the Pipeline Authority to determine their effect on construction. Advice on drainage problems at Red Hill was given to the Department of the Capital Territory in connection with determination of land values. A major report on the groundwater hydrology and drainage of proposed suburbs at Lanyon was completed for the National Capital Development Commission. Advice was also given to the Commission in respect of groundwater seepages affecting proposed development of new suburbs at Isaacs and Gilmore.

Hydrochemistry

As part of the study for the ACT hydrogeological map, regional variations in water chemistry have been studied, using a computer package of multivariate statistics. Results from this study indicate that recharge conditions are as important as aquifer-rock type in determining water quality in a stable mineralogical environment.

Hydrogeological map of the ACT and environs

Progress towards production of a hydrogeological map of the ACT and environs at 1:100 000 scale continued. The basis for the map is the information on variations in groundwater quality and quantity contained in several hundred water-bores drilled in the area. Fieldwork in 1981 included the checking of bore locations and other data. Drafting of the topography and general geology plates began.

Water-levels in the ACT observation bore network were regularly monitored.

Hydrology of Lake George

Monitoring of Lake George (NSW) levels and salinity continued, in order to maintain continuity of the hydrograph, which is one of the longest in Australia. The lake level dropped early in 1981 with a parallel loss of salts. It rose slightly to a level of 1.23 m on 1 October, when electrical conductivity of the water was 9000 µS/cm, equivalent to a salt content of 6000 mg/l. Adjustments were made to the lake-water-balance model program.

Orroral River Representative Basin

Preliminary work was undertaken by G. Sparksman of this group and E.J. Best of the Canberra College of Advanced Education on the hydrogeology of the Orroral River Representative Basin in the southern part of the ACT. The basin is in Siluro-Devonian granite, and a study of fracturing is to be followed by experimental water-bore drilling.

Upper Yass River catchment hydrology

Work continued on the hydrogeology of a small experimental catchment in the Upper Yass Representative Basin (NSW) adjacent to the ACT border. The work is being done in collaboration with Dr B. Williams of the CSIRO Division of Land Use Research.

The Quaternary stratigraphy has been expanded to include the Poppett Pedoderm as the oldest Quaternary unit, occurring primarily on the slopes above the valley floor. The site of a possible Aboriginal artifact has been marked, and an associated sample of charcoal is being radiocarbon-dated by the Prehistory Department of the Australian National University.

Extensive sampling of the water from the surficial aquifer was undertaken after heavy winter rain; samples are being chemically analysed. Results of hydrogen isotope analysis on samples of fractured-rock groundwater by the Australian Atomic Energy Commission confirm the method of recharge to this aquifer deduced from conventional water chemistry.

HYDROGEOLOGY OF FRACTURED-ROCK AQUIFERS

by

J.R. Kellett

Hydraulic behaviour of a fractured-volcanic-rock aquifer

Two experimental borefields were completed in the southern Tuggeranong Valley, ACT. The bores are in moderately fractured, interbedded Silurian rhyodacites and tuffaceous sedimentary rocks which represent one of the six major rock provinces in the ACT regional hydrogeological study. It is likely that the bores will eventually be used as a water supply for expanded tourist and recreational facilities at Lanyon station.

Forty-eight-hour pump tests were done in each borefield, and the pumping bores and observation wells were sampled throughout the tests.

Analysis of the tests indicates that:

(i) Well loss is a highly significant component of drawdown in uncased bores, except along the dominant direction of jointing.

(ii) Systematic deviation from Thiess-Jacob theory occurs within 50 m of the pumping wells, but becomes less pronounced with distance away from the well; this is true in the laminar flow regime after corrections for well storage effects.

(iii) Response of piezometers in the surficial aquifers during pumping of the fractured rock bore indicates that there is significant interaction between groundwaters in the fractured rock and in the surficial aquifers but the mixing is not reflected in hydrochemical measurements of bore discharge water. Apparently reaction rates in the weathered zone are dominant over residence times.

(iv) Salinity gradients in observation wells indicates that piston flow is a valid model on the hillslopes (the classical recharge zone) but does not necessarily describe the dynamics in the drilling zone. Stagnation points and zones of deep circulation in the fractured rock are better defined by the analysis of variance of groundwater potentials and salinities in the fractured-rock and surficial aquifers.

Tharwa water supply investigation, ACT - induced groundwater recharge in a major fracture zone

BMR was requested by the Department of Housing & Construction to investigate the availability of a suitable groundwater supply for domestic purposes for the village of Tharwa. Required yields are 8 l/s (stage 1) and 18 l/s (stage 2).

Tharwa lies on the Murrumbidgee River, which in this area follows the trace of a major reverse fault separating Upper Silurian acid volcanics in the east and granites of the Murrumbidgee Batholith in the west. The mean initial discharge values of bores in the granites and volcanics away from the fault is 0.5 l/s, but safe yields may be considerably less than this during periods of drought.

The hydrogeological environment around the fault zone (Fig. G6) is the most promising in the area for a borefield because the Murrumbidgee River is a perennial line source of recharge which eliminates uncertainties with regard to safe yield, and the spacing of fractures in and near the fault zone is sufficiently close to permit production rates of the order required. A

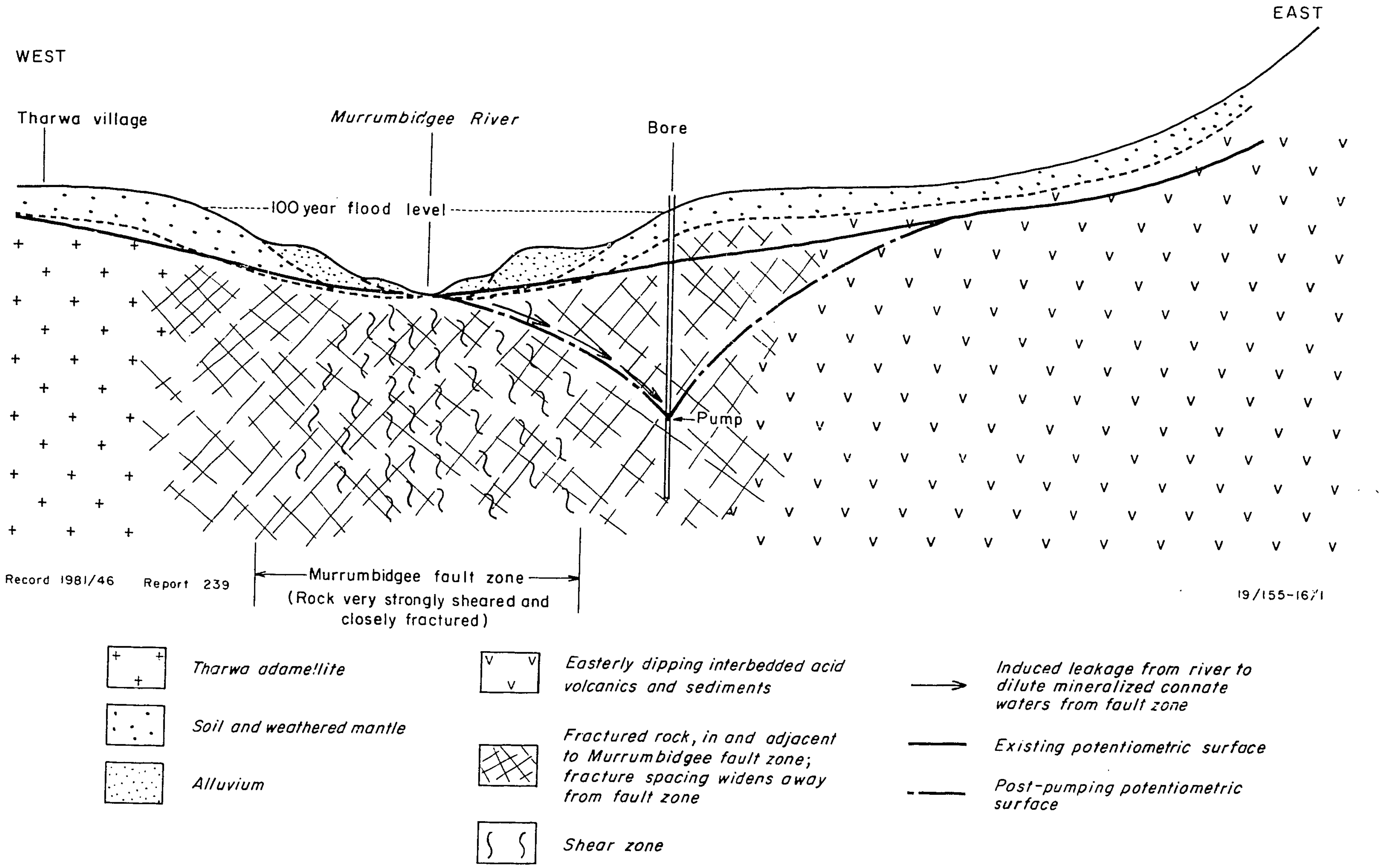

Fig. G6 Hydrogeological cross-section, Tharwa water supply (length of section about one kilometre) disadvantage of the site is that connate waters of the fault zone are generally more saline than in the country rock, but adequate dilution could be attained if sufficient quantities of river water are induced to mix with groundwater during pumping.

Accordingly, two trial bores were drilled in the volcanics 50 m away from the river. Bore 316 intersects vertical tensile fractures which trend parallel to the river, and it is expected that chemical analysis of bore discharge water throughout a pumping test would define the hydrogeochemical parameters of the connate groundwater since there would be negligible river inflow. Bore 323 intersects open fractures trending oblique to the river, providing hydraulic continuity between the groundwater and river water. Chemical analyses of this bore through a pumping test should describe mixing trends.

Forty-eight-hour constant-discharge pumping tests, eight-hour step-drawdown, and 24-hour recovery tests were carried out in each bore. The discharge of bore 316 was 1.5 l/s and in bore 323 the rate was above the pump capacity of 5 l/s.

Chemical analyses of bore water throughout the constant discharge tests indicate that the connate groundwater is unacceptably high in sulphate and iron, both of which are products of oxidation of pyrite in the mineralised fault zone. As expected, dilution of saline groundwater with river water was attained in bore 323 as soon as the water-table fell below river level, but no dilution occurred in bore 316.

The investigation showed that adequate quantities of groundwater can be extracted from the fractured rocks adjacent to the fault zone. However, it was also found that storage of saline water in the fault zone is large, and therefore large inflows of river water are needed for adequate dilution. In fact, water quality deteriorates through pumping because the proportion of river water decreases with radial expansion of the wide and flat cone of depression in the high transmissivity aquifer. Therefore, a borefield in these rocks would require very careful management, ensuring high pumping rates of short duration; the groundwater would also require treatment before reticulation.

The feasibility of increasing the proportion of river water near the pump intake by opening the fractures between the bore and the river with explosives is being investigated.

A third exploratory bore was partly drilled in Sawyers Gully to the south of Tharwa. The bore is at the intersection of a prominent northeast lineament with the contact between the Booroomba Leucogranite and Tharwa

Adamellite. The contact is well-defined by lines of springs, suggesting that the adamellite is a low-permeability boundary which impedes groundwater throughflow from the closely fractured leucogranite. Groundwater quality (TDS < 500 mg/l) is superior to that in the volcanics, but adequate flow rates have not yet been obtained.

URBAN GEOLOGY, ACT

by

G.A.M. Henderson

Canberra 1:10 000 Engineering Geology Map Series

The Canberra 1:10 000 Engineering Geology Map Series comprises six map sheets which cover most of the urban area of Canberra. Data from outcrop mapping, project drilling, seismic refraction traverses, and temporary rock exposures in excavations, are compiled to give a presentation of rock type distribution and subsurface weathering characteristics relevant to engineering geology. One map was published in 1980, but issue of further maps in the series has been delayed by lack of funds for publication. During the year work was directed towards completing compilation of the two final maps, North Canberra and South Canberra. Augering data were obtained from engineering foundation investigation reports, and three drillholes were put down by BMR near Jerrabomberra Creek at Fyshwick, in the South Canberra Sheet area, to obtain further data. Some outcrop checking was also done at Fyshwick and in the North Canberra Sheet area.

The current state of completion of the maps (October 1981) is as follows.

Coppins Crossing	- published
Central Canberra	- map edited, notes awaiting editing
Woden-Weston Creek	- map and notes awaiting editing
Belconnen	- map and notes awaiting editing
North Canberra	- map and notes compiled
South Canberra	- map 80% complete

Canberra - Queanbeyan 1:50 000 Geological Map and Notes

The geological map of Canberra, Queanbeyan, and environs at 1:50 000 scale was printed early in 1981. Issue of the map is awaiting printing of the commentary which is in press.

Engineering geology of Canberra

A paper is being prepared, jointly with E.J. Best of the Canberra College of Advanced Education, on the engineering geology of Canberra for submission to the Association of Engineering Geologists' series on the engineering geology of cities of the world. It summarises aspects of engineering geology in the development of Canberra including foundations for buildings and structures, major tunnel excavations for sewerage mains, construction materials, geological constraints on development, and environmental concerns. Figures have been drafted and most sections of the text have been written.

Geological factors in dam construction

A review of geological factors in the location, design and construction of large dams in the Canberra area was undertaken by E.J. Best of the Canberra College of Advanced Education while on professional-work-experience leave with BMR late in 1980. A paper on the subject was published in the BMR Journal.

Gravel for ACT rural roads

An investigation of possible sources of road gravel in the southern ACT was undertaken by G. Sparksman at the request of the Department of the Capital Territory. Recommendations were made for the development of a pit in weathered granite.

Parliament House site, Capital Hill

Excavation began in January 1981 to prepare the site for the construction of the new and permanent Parliament House on Capital Hill, Canberra. At the request of the Parliament House Construction Authority geological mapping is being carried out as excavation proceeds, in order:

(1) to check, where possible, the accuracy of the geological interpretation derived from test pitting, trenching, and drilling carried out in 1979 by engineering consultants;

(2) to provide a geological map of the foundations based on the newly created rock exposures. The mapping provides also an opportunity to observe features of an important unconformity in the Canberra stratigraphy which occurs at the site.

Earthworks involve the removal of up to 22 m of soil and rock from the top of the hill. This material is being placed around the western and southern sides to build up former low-lying areas, and a considerable surplus is being removed from the site. In the centre of the site, where excavation is deepest, many vertical rock faces, some up to 10 m high, are being formed. These are being mapped and sketched, and are providing excellent exposures of the two unconformable rock units - the Lower Silurian Black Mountain Sandstone and the Middle Silurian Camp Hill Sandstone Member. A third unit, the Lower Silurian State Circle Shale, occurs around the northern and western margins of the site. Some problems remain at this stage regarding the stratigraphic and structural relations between the State Circle Shale and Black Mountain Sandstone; the shale appears to overlie the sandstone which is the reverse of the regionally observed and interpreted relationship.

Excavation work is scheduled for completion in December 1981.

MAP EDITING AND COMPILATION

by

G.W. D'Addario

STAFF: G.W. D'Addario, W.D. Palfreyman, J.E. Mitchell (on leave without pay until 26 January), A.S. Mikolajczak, W.J. Fetherston (until 30 January), R. Chan, G.A. Young (from 22 September)

A report was prepared by the BMR Earth Science Atlas Committee, under the convenership of the Section Head, in which recommendations were made on future developments of the Atlas and management of the project. In May the Map Preparation Monitoring Committee was set up, with E.K. Carter as Convener, to facilitate the preparation and production of maps and their commentaries.

G.W. D'Addario is a member of the committee, which has met four times. D'Addario also attended the fortnightly meetings of the Publications Co-ordinating Committee. Two meetings of the Map Committee were held, under the chairmanship of the Branch Head, on 8 December 1980 and 30 June.

Comments were made on a draft set of standard lithological patterns and on a list of standard abbreviations which it is proposed should be published as a supplement to the booklet 'Symbols used on geological maps'.

MAP EDITING

Twenty-one maps were edited:

1:250 000 geological series - colour edition - 8 maps:
Yarrie, Napperby (2nd Edn.), Broome, Pender, La Grange, Duchess-Urandangi Special, Alligator River (2nd Edn.), Alice Springs (2nd Edn.).

1:100 000 geological series - colour edition - 7 maps:
Duchess Region, Dajarra, Nabarlek Region, Alice Springs Region, Lawn Hill Region, Ardmore, Alsace.

1:500 000 geological maps - colour edition - 1 map:
Geology of Southern Prince Charles Mountains.

1:1 000 000 geological maps - colour edition - 2 maps:
Geology of the Canning Basin, Plates 1 and 2.

1:10 000 000 maps - BMR Earth Science Atlas of Australia - 2 maps:
Petroleum and oil shale, coal.

1:10 000 Engineering Geology Series - 1 map:
Central Canberra.

Editorial checks were made and assistance or advice given on four maps:

Irian Jaya Geological Mapping Project. Taminabuan 1:250 000 geological map
(Edit of preliminary edition)

Geological World Atlas (C.G.M.W.) Sheet 16 (Editorial check).

Atlas of Australian Resources, 3rd series (for Geographic Branch, Division of National Mapping). Geology of Australia 1:5 000 000 (editorial check). Surface rock types 1:10 000 000 (supervision of compilation and editorial check).

Editing is in progress on 6 maps:

1:250 000 geological series - colour edition - 1 map:
Youanmi.

1:100 000 geological series - colour edition - 5 maps:
Strangways Range Region, Selwyn Region, Kuridala Region, Arltunga-Harts Range Region, Mary River-Point Stuart Region.

Two maps of the 1:10 000 A.C.T. Engineering Geology Series are awaiting editing (acceptance check complete) pending a decision on publication: Belconnen, Woden-Weston Creek.

MAP COMPILATION

Various aspects of map compilation including the design of map legends were discussed with authors and draftsmen. D'Addario completed the draft commentary to accompany the Surface Drainage and Continental Margin map of the BMR Earth Science Atlas. Palfreyman completed a final draft of notes to accompany the 1:2 500 000-scale Geological Map of Australia (Bulletin 181) and substantially completed a commentary to accompany the 1:5 000 000 scale 'Geology of Australia' map of the 3rd series, Atlas of Australian Resources. He also spent some time supervising the activities of the Stratigraphic Index and Mineral Reports group.

INDEXES AND MINERAL REPORTS

by

K. Modrak

STAFF: K. Modrak, R. Lorenz, L. Kay (retired 11 June), J. Morrissey (part-time), H. Harrison (commenced 7 September).

STRATIGRAPHIC INDEX

Literature on Australian geology received in the BMR Library was indexed under the headings - author, State, 1:250 000 Sheet (1:100 000 if necessary), detailed location, basin or structural province, keywords, and stratigraphic names - and then entered via terminals onto the GEODX computer database.

Current literature indexed is entered from the data sheets into the database on a monthly basis; average monthly input for the year was 73 references containing 609 stratigraphic names. An increase in input over the last year can be attributed mainly to the indexing of the "Geology of Western Australia" and the Australasian Institute of Mining and Metallurgy "Coal volume", carried out by R. Lorenz.

Literature indexed prior to December 1978 was prepared by contract for input to the GEODX database. Already two contracts have been completed for a total of $3000 covering author cards beginning with the letters A to Gi: 1635 references with 13 303 stratigraphic names. A third contract, about the same size as the first two combined, was started in October 1981.

The addition of R. Lorenz to the group has allowed the Stratigraphic Index to take advantage of computerisation with the following projects:

(1) Special emphasis was made to index Antarctic stratigraphic names to ensure a comprehensive coverage.

(2) A progress report on the computerisation of the Stratigraphic Index and a request for State survey requirements were compiled.

(3) Lists of journal articles relevant to Australian geology and scanned for stratigraphic names were compiled under subject headings and circulated to BMR staff. This service was started in March and is intended to be carried out on a two-monthly basis.

Some 309 new stratigraphic names, 92 of which were previously reserved, and 118 definitions of units, were indexed in the year ended 30 September 1981. One-hundred-and-twenty-eight new names were reserved for use by prospective authors; and 84 definition cards were submitted by authors, through Divisional Stratigraphic Nomenclature Subcommittees of the Geological Society of Australia, and were filed.

Six bimonthly Variation Lists (Nos. 42-47) and one annual Deletion List (No. 8) noting additions to and deletions from the Central Register, were compiled and distributed to Stratigraphic Nomenclature Subcommittees, State geological surveys, universities, and mineral exploration companies. Variation List No. 46 was the first to be completely computer-generated.

Inquiries and visits from authors, State survey officers, and others regarding stratigraphic names, definitions, and literature references were handled as they arose.

A report on the Stratigraphic Index covering the period September 1979 to April 1981 was compiled for the Convener, Stratigraphic Nomenclature Committee, Geological Society of Australia.

With the development of the computerised database, considerable time has been spent on maintenance and miscellaneous projects:

(1) An instruction manual for the Stratigraphic Index was compiled.

(2) Instruction sheets for the use of GEODX were compiled.

(3) A handout on the Stratigraphic Index was produced.

(4) Extensive work was carried out to standardise the input.

MINERAL INDEX AND MINERAL REPORTS

The report on fluorite occurrences in Australia, begun in 1978 by P.J. Kennewell, was amended by R.P. Lorenz. A copy was sent to all State geological surveys for comment. Suggestions and additional information from the States are presently being incorporated into the final draft.

MUSEUM

by

M.B. Duggan

STAFF: M.B. Duggan (from 28.1.81), J.D. Reid, M.S. Amar (part-time)

Collections

The BMR collection of specimen minerals has increased in number by about 35 specimens with a combined value of about $4000.

Specimens of huebnerite on quartz, mesolite, hemimorphite, okenite, atacamite, and pyrrhotite were purchased and specimens of vanadinite, rosasite, veszelyite, siegenite, and boulangerite were obtained by exchange.

A variety of zeolites was collected in Tasmania and northern New South Wales including natrolite, analcime, chabazite, phillipsite, and thompsonite.

Studies are being undertaken on Museum specimens of unknown or doubtful identity, to resolve doubts.

Education

Ten school groups, totalling about 200 students and teachers, visited the Museum. Most of these were accommodated in the Museum but two larger groups were moved to the second floor meeting room where a suitable display was provided. Most groups were primarily concerned with study of the rock-forming minerals, the ore minerals, and crystallography.

Services to visitors other than school groups

Apart from school parties, about 280 visitors were recorded. About half of these had specific enquiries or rock and mineral specimens for identification.

A variety of gemstones was also brought in, either for identification or for assessment as natural or synthetic stones.

Advice is being provided to the Queanbeyan Historical Museum on the setting up of a display of the geology and mining history of the district.

Exhibitions

The Museum continued to participate in regular Gem and Mineral shows.

The Gemboree held in Devonport attracted a large number of visitors. The BMR display consisted of minerals illustrating the seven crystal systems.

Displays were also presented at the ACT Lapidary Club (coloured gemstones and the seven crystal systems), Waverley Gem Club (carbonate minerals), and Adelaide Gem and Mineral Club (Australian minerals) shows. All shows were of a high standard and very well attended, and the BMR displays were well received and greatly appreciated.

Research

A project has been commenced on the occurrence of secondary minerals in the Gerringong Volcanics on the New South Wales south coast to investigate possible relationships between zeolite assemblages and the rank of associated coal deposits. As a result of fieldwork it is clear that zeolitisation was contemporaneous with the volcanic activity and hence no direct relationship is likely. However it is possible to recognise the existence of fossil hydrothermal systems in the volcanic sequence and this aspect is being studied.

TRANSIT ROOM

by

M.S. Amar

The number of samples submitted by field parties and sent to contractors or to BMR laboratories for chemical analysis, thin sectioning, or other determinations, in the period 1 October, 1980 to 30 September, 1981, was (comparative figures for the preceding twelve months in brackets):

Impregnated thin sections	151	(47)
Polished thin sections	514	(352)
Normal thin sections	2 160	(5 759)
Standard thin sections	250	(303)
Isotopic age determinations (various)	109	(132)
X-ray diffraction determinations	57	(37)
Chemical analyses (various)	2 174	(4 744)
Other	-	-
Total:	5 415	(11 374)

CONFERENCES AND COURSES

Members of the Section attended the following training courses and conferences:

26-30 November 1980	Symposium on the Cainozoic Evolution of Continental Southeast Australia, Canberra. G. Jacobson, G.A.M. Henderson, J.R. Kellett.
4 March 1981	Fourth Australian Tunnelling Conference, Melbourne. E.G. Wilson.
30 March - 1 April	AMF Course 'Geoscience numeric and bibliographic data', Adelaide. R.P. Lorenz.
5-7 June	Combined Seminar, Mineralogical Societies of New South Wales and Victoria, Sydney. J.D. Reid.
2 July	Seminar on Soils of Canberra, Canberra. G. Jacobson.
8-10 July	1981 Conference on Environmental Engineering, Townsville: Engineering for the Marine Environment. E.K. Carter.
29-30 September	Meeting of BMR-State survey information specialists, Canberra. R.P. Lorenz.

Participation in gem and mineral exhibitions is given in the section titled 'Museum'.

BAAS BECKING GEOBIOLOGICAL LABORATORY

Supervising Scientist: M.R. Walter

SEDIMENTOLOGICAL STUDIES OF SPENCER GULF

by

R.V. Burne

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

The levels of intertidal environments of prograding Holocene coastal complexes of northeast Spencer Gulf have been precisely measured and their relation with the tidal range determined. Beach ridges and the top of subtidal sea-grass deposits are the best indicators of relative sea level, and the elevation of preserved examples of these has been established along transects across intertidal and supratidal plains. ^{14}C dating has been carried out on unaltered mollusc shells recovered from beach ridges and the base of the regressive intertidal facies above the subtidal sea-grass field facies. Sea-grass root fibres and shell hash from the top of the buried subtidal facies have also been dated. A Holocene sea-level history has been constructed for northeast Spencer Gulf, and shows the following events: (1) 6000-4000 years B.P. - probable construction of a shingle ridge at +3-4 m at the peak of the Holocene transgression, followed by about 1 m fall of sea level but little progradation, owing to low rates of carbonate production; (2) 4000-3000 years B.P. - formation of regressive carbonate shorelines with fall of relative sea level from about +2 m to about 1.5 m, and the construction of beach ridges; (3) 3000-2000 years B.P. - no beach ridge construction along surveyed transects, but continued progradation of shorelines with a further 0.5 m fall in relative sea level; (4) 2000 years B.P. to present - construction of beach ridges accompanied shore-line progradation, and a fall in relative sea level of 0.5 - 1.0 m. A contributing cause of relative movement of sea level in the region may be continuing tectonic uplift, as evidenced by the high seismicity of the adjacent Flinders Ranges.

Studies of the composition of the cool-water skeletal carbonate sediments forming in Spencer Gulf, have been undertaken. Four environments can be distinguished: deeper marine areas (10-20 m); shallow subtidal platforms and banks (2-10 m); intertidal and supratidal zones; and coastal springs and lakes fed by saline continental groundwaters. The sediments are predominantly bioclastic carbonate sands; muddy sediments occur in protected intertidal environments. The most common grain types are gastropods, bivalves, foraminifera, coralline algae, and quartz. Indurated non-skeletal carbonate grains have not been seen. Composition of the sediment varies little between environments, but considerable textural variation results from variation in the stability of the substrate, hydrodynamic conditions, depth of water, period of tidal inundation, supply of terrigenous grains, temperature, and salinity. The Spencer Gulf data suggest that temperature, and particularly minimum temperature, controls the distribution of skeletal and non-skeletal grain associations in high salinity environments. The textures of the sedimentary facies of Spencer Gulf closely parallel those of equivalent environments in warm-water carbonate provinces.

The relationships between frequency of tidal inundation, topography, depositional environment, and sedimentary facies have been examined in four contrasting areas of the prograding carbonate shoreline. Although exposed coasts and protected coasts give rise to different associations, both show a distinction between frequently inundated low intertidal environments in which bioturbated and homogenised sediments form, and high intertidal zones characterised by laminated facies.

Spencer Gulf contrasts with other well-described areas of intertidal carbonate deposition in that it has a moderate tidal range (3.5 m) and cool waters (10-26°C), and lies within a semi-arid climatic zone. Comparison with data from the Bahamas, Florida, and the Persian Gulf reveals close parallels with the environments and facies of Spencer Gulf mangrove tracts, cyanobacterial marshes, intertidal creeks, and low intertidal zones. However, the greater tidal range of Spencer Gulf allows the development of extensive intertidal flats. Broad tidal flats are generally associated with areas of terrigenous rather than carbonate sediments. An idealised sedimentary sequence for Spencer Gulf peritidal sedimentation is intermediate in character between those derived from studies in the Bahamas and the Persian Gulf.

It is not an area of extensive carbonate lithification; in fact extensive deposition of aragonite is only occurring around saline groundwater springs at Fisherman Bay, where waters from a confined Tertiary carbonate aquifer reach the surface. Diagenesis in the vicinity of these springs cannot be assigned to commonly recognised zones of diagenesis in that the environment is neither vadose, with trickle-type percolation of water through air-filled cavities, nor is it phreatic, with water-filled pore space and either static conditions or lateral laminar flow. Instead it is an environment of interconnected conduits through which waters may move with turbulent flow. It is thus analogous to a cave system, but flow is directed upwards, towards the piezometric surface of the Tertiary aquifer, which lies above ground level at the site of the springs. Close petrological similarities between the limestones forming at Fisherman Bay, and ancient examples of laterally extensive limestones with tepee structures and spelean cements suggests that the environment of a petrifying spring fed by formation waters may be a geologically important indicator of arid zone paralic environments, where surface run-off is minimal.

ISOTOPE STUDIES IN THE MODERN ENVIRONMENT

by

L.A. Plumb

STAFF: R.V. Burne, James Ferguson, D. Fitzsimmons, P.E. O'Brien, L.A. Plumb, M. Thomas.

SULPHUR ISOTOPE DISTRIBUTIONS IN MARINE ENVIRONMENTS

The study of sulphur isotope fractionation in the intertidal sediments at Mambray Creek in Spencer Gulf (SA; Plumb in BMR Report 222) is the first extensive survey of isotope distribution in an intertidal environment, and led to a survey of data available for other marine environments. The Mambray Creek data are compared in Fig. B1 with those already reported for intertidal environments and with data from a number of different subtidal environments. The Mambray Creek values display a normal distribution which is characteristic for a system essentially open to sulphate. This contrasts with patterns like those of the Black Sea and Californian basins, which show trends to heavier values. These occur in deep sediments where the sulphate supply is limited and gradually becomes enriched in ^{34}S as a consequence of fractionation during bacterial sulphate reduction. The distribution of the new values encompasses those from previous studies of intertidal environments.

The mean value of the isotope distribution in the sulphides at Mambray Creek (-17°/oo) falls within the range of means (-13°/oo to -31°/oo) for subtidal precipitated sulphides. It is slightly less than the mean value in the surface sediments of the Baltic Sea for which there is otherwise a comparable pattern. For the subtidal environments, no account has been taken of the relative proportions of pyrite and acid volatile sulphides in the representation of the distribution patterns. In general, pyrite is the principal and final product and may be slightly more negative than the acid volatile and free sulphide. The Baltic Sea distribution is predominantly for pyrite and does not show an influence of the heavier pore water sulphide (see Fig. B1) which is indicative of sulphate depletion at depth and is consistent with the pyrite

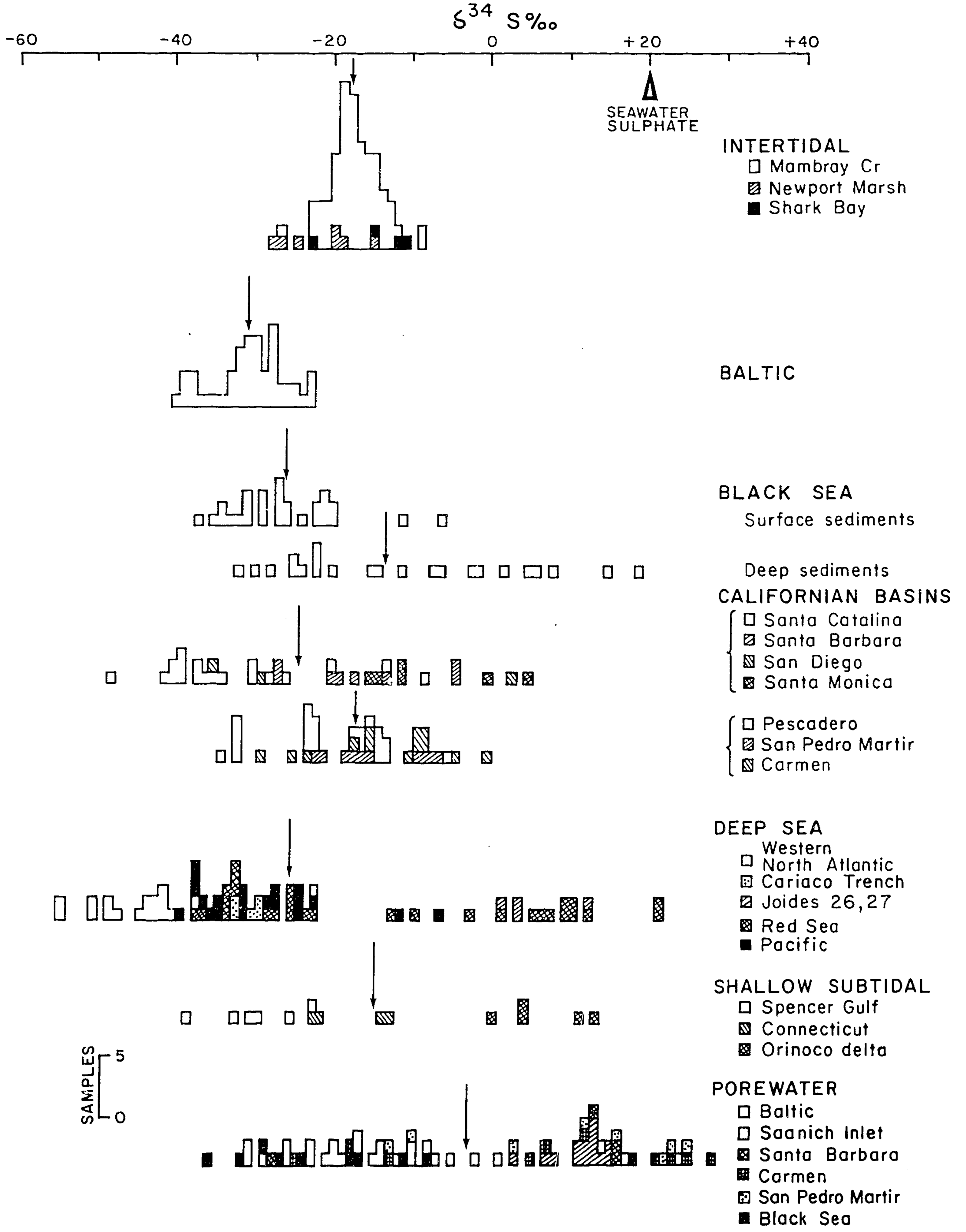

Fig.B1 Isotope distribution patterns of sulphides from recent marine sediments. Vertical scale shows frequency and arrows show mean values of each group.

forming at the sediment-water interface in an open system. The Black Sea distribution has open and closed patterns in the surface and deep sediments respectively (Fig. B1). The extent to which a sediment can become closed to sulphate is influenced by the rate of sedimentation. Rapid sedimentation allows the burial of more organic material and promotes enhanced metabolic activity, and consequent depletion of sulphate, in the deeper sediments. This simple differentiation appears to apply in comparison of the distribution patterns for the Baltic sediments (rate about 1 cm $-1000y^{-1}$) and the Californian basins (rate for Santa Barbara basin = 300 cm $-1000y^{-1}$. The sedimentation rate also influences the suitability of the preserved organic matter for microbial metabolism. The more slowly deposited material is more highly degraded and thus more complex and less readily available. This may indirectly increase the extent of fractionation by lowering the rate of sulphate reduction. The most negative $\delta^{34}S$ values have been found in cores from deep-sea sediments of the western north Atlantic where sedimentation rates were of the order of 1 cm $-1000y^{-1}$.

At Mambray Creek (Skyring in BMR Report 230) the yearly rate of sulphate reduction is 6.5-12 mol m^{-2}.

This is equivalent to 2-3 mol S $l^{-1}y^{-1}$ for 1 cm depth and is an order of magnitude greater than the highest value reported for subtidal environments. Such rapid sulphate reduction reflects the availability of easily metabolisable organic material from the cyanobacterial mat and may explain the smaller fractionation compared with the other open systems of the Baltic and Black Sea surface sediments. Thus the isotope distribution in an intertidal environment may be that of a system open to sulphate, and while the fractionation is not identical with that in other environments open to sulphate neither is it discrete from fractionations in systems closed to sulphate. Neither the pattern nor the extent of fractionation is unique to the intertidal environment.

SULPHIDES IN TIDAL CHANNELS, SHARK BAY, WESTERN AUSTRALIA

Sulphur isotopes in algal laminated sediments have been sampled from tidal flats marginal to Lharidon Basin and Gladstone Embayment, at Shark Bay (WA; Fig. B2). The site marginal to Lharidon Basin is subject to intermittent desiccation, but at the other location this is unlikely, since the channel has a direct connection with the South Gladstone Embayment. The sediments there were covered by 20 to 30 cm of water when samples were taken, while those at Lharidon Basin were topped by halite crystals.

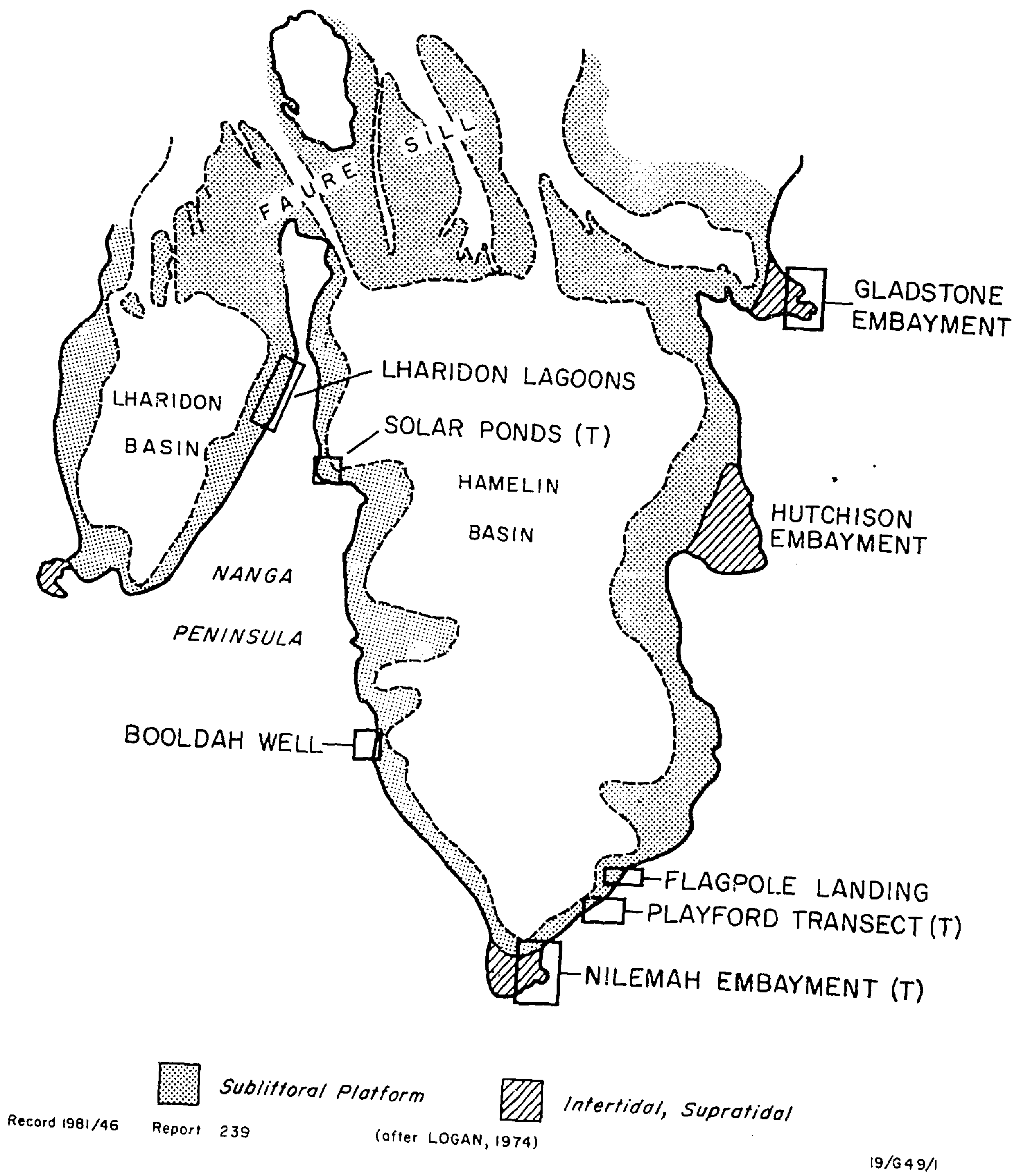

Fig. B2: Groundwater sampling locations at Hamelin Pool and Lharidon Basin. Transects were established at those locations marked with a (T).

Sulphide concentrations and isotope values for both sediments are given in Tables B1 and B2. The range of values (-17.2 to -32) is equivalent to fractionations of 1.038 to 1.052 relative to seawater sulphate. This is not distinguishable from fractionations in other marine environments. Minute quantities of zinc-reducible sulphide (presumably pyrite) were found and its isotope distribution was generally ^{32}S-enriched compared with the acid labile sulphide. This relationship is common in sediments, but has most often been explained in terms of the acid labile sulphide being produced most recently in a system closed to sulphate. The trend of increasing ^{32}S content with depth in these sediments conflicts with the suggestion of a closed system. The same type of pattern has been observed in sediments of the Santa Catalina Basin and the Bali Trough over much greater depths.

ISOTOPE STUDIES IN SHARK BAY, WESTERN AUSTRALIA

Gypsum, groundwater sulphate, and sulphides have been analysed for sulphur isotope distribution and are detailed in Table B3. The sulphate values show an intense marine influence at both Nilemah and the Solar Ponds (Fig. B2 19/G/49/1). Even birridas (salt lakes) 1-2 km from the present shoreline have gypsum which is of marine origin. Along the Nilemah transect (see Fig. B3) there is an indication of lighter (e.g. +18.5°/oo) continental sulphate in samples near the beach ridges. These samples also have lower salinities consistent with a continental origin. Fluctuation of the values across the supratidal plain may indicate a zone in which either continental or marine influence has dominated at different times. Deuterium and oxygen isotope analyses of the groundwaters are being undertaken and should help the interpretation. A different situation exists at Flagpole Landing where there is a noticeable groundwater seepage at the base of the dunes. The sulphate in this has a value of +17.9°/oo and is thought to be influenced by the nearby flow of borewater in which sulphate is +13.6°/oo.

Dark sediments below the water-table in the Nilemah supratidal plain (Table B3: A4, B23, B28) were initially thought to be principally sulphide, but acidification yielded only minor quantities (6-7$\mu gS^{=}$/g wet sediment) and a black amorphous residue. In the low intertidal sediments (Nilemah transect A2), however, sulphide concentrations were of the order 500$\mu gS^{=}$/g wet sediment. The sulphides from the supratidal sediments are more ^{32}S enriched than the

TABLE B1

SULPHIDE CONCENTRATIONS AND ISOTOPE DISTRIBUTIONS IN CHANNEL SEDIMENTS OF TIDAL-FLAT ENVIRONMENTS AT SHARK BAY, WESTERN AUSTRALIA

Depth Interval	Acid labile sulphide			
	Lharidon Basin		Gladstone Embayment	
cm	$mg\ g^{-1}$ (dry wt)	$\delta^{34}S$°/oo	$mg\ g^{-1}$ (dry wt)	$\delta^{34}S$°/oo
0 - 5	0.47	-17.2	2.4	-19.7
5 - 10	0.70	-19	0.93	-21.3
10 - 15	0.48	-24.1	0.15	-25.1
15 - 20	0.19	-23.4	0.14	-24.9
20 - 25	0.09	-25.3	0.20	-27.2
25 - 30	0.10	-25.1	0.06	-25.5
30 - 35	0.17	-27.6		
35 - 40	0.10	-32		
40 - 50	0.08	-29.4		

TABLE B2

SULPHUR ISOTOPE DISTRIBUTION FOR ZINC-REDUCIBLE SULPHIDE FROM SEDIMENTS IN TIDAL CHANNELS AT LHARIDON BASIN AND GLADSTONE EMBAYMENT, SHARK BAY, WESTERN AUSTRALIA

Site	Depth interval cm	$\delta^{34}S$°/oo
Lharidon	0 - 20	-25.4
Basin	20 - 35	-27.7
	40 - 55	-28.8
Gladstone	0 - 10	-23.5
Embayment	10 - 15	-25.4
	20 - 25	
	25 - 31	- 28.0

TABLE B3

SULPHUR ISOTOPE DATA FOR GYPSUM, GROUNDWATER SULPHATE, AND SULPHIDE SAMPLES FROM SHARK BAY, WESTERN AUSTRALIA

			$\delta^{34}S$ °/oo
Gypsum			
Nilemah transect	A 5		+22.3
	A 6		+22.2
Solar Ponds			+22.4
Inland birrida	1		+22.1
	2		+22.5
	3		+22.2
Groundwater sulphate			
Nilemah transect	B 20.14		+18.5
	21 (5)		+20.3
	22 - 6		+20.5
	22		+20.0
	22.15		+18.9
	23		+18.9
	23.33		+20.5
	24 - 12		+19.9
	25		+20.0
	25 (5)		+20.9
Solar Ponds 1			+21.8
2			+22.0
3			+21.6
Solar Ponds transect	31.6		+20.8
	33.16		+21.4
	24.47		+21.4
Playfords transect			+23.4
Flagpole Landing			+17.9
Bore water			+13.6
Sulphides			
Nilemah transect	A2	acid labile	-14.2
		zinc reducible	-17.2
Nilemah transect	A4	acid	-26.6
	B23	labile	
	B28	zinc	-32.2
		reducible	

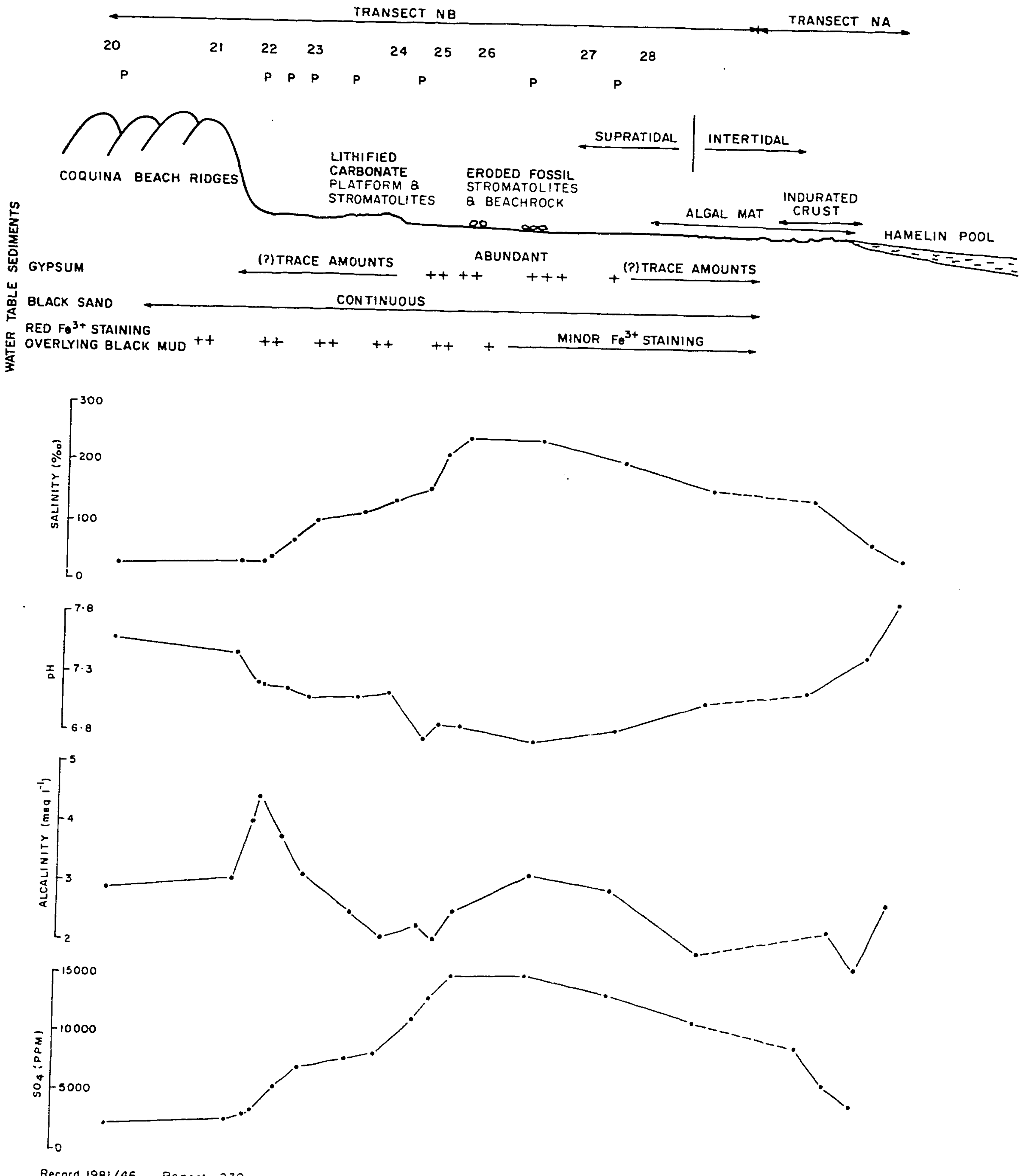

Fig.B3 CHEMICAL COMPOSITION OF GROUNDWATERS IN THE PERITIDAL ZONE OF NILEMAH EMBAYMENT more abundant intertidal material (-26.6 and -32.2 versus -14.2 and -17.2). Relative to seawater sulphate these values represent the upper and lower ranges of fractionation in marine environments.

GROUNDWATERS IN A SEMI-ARID COASTAL HOLOCENE CARBONATE ENVIRONMENT AT HAMELIN POOL AND LHARIDON BIGHT, WESTERN AUSTRALIA

by

James Ferguson

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

Coastal areas around Hamelin Pool and Lharidon Bight contain three main types of groundwater: (1) marine brines formed from the hypersaline seawater of Hamelin Pool and Lharidon Bight, (2) continental groundwater which occurs partly as freshwater lenses within Pleistocene sands and coquina beach ridge, and (3) artesian groundwater which discharges from boreholes drilled to the artesian aquifer system which underlies the near-surface sands.

Much of the variation of the hydrological regime around Hamelin Pool and Lharidon Bight is related to the local topography of the coastal areas, which produces intertidal/supratidal zones varying in breadth from about 100 metres at the Playford site south of Flagpole Landing, through about 300 metres at Flagpole Landing, to several kilometres in Nilemah, Gladstone, and Hutchison Embayments (Fig. B2).

Continental groundwater in the coastal areas occurs as freshwater lenses in the coquina beach ridges and also as considerably more saline waters in the underlying Pleistocene sands. These saline waters could be part of a regional groundwater system or they may have formed by downward percolation of freshwater from the overlying beach ridges. Possible exceptions of this type of groundwater regime occur at Flagpole Landing and Gladstone Embayment. At Flagpole Landing groundwater discharging from the base of the coquina dunes onto the supratidal flats may contain artesian water from an inland borehole. At Gladstone Embayment there may be extensive groundwater drainage into the high supratidal zone and saline flats immediately landward. Also, the supratidal sediments in this area are predominantly stiff impermeable clays, in contrast to the highly permeable carbonate sands and silts common in other coastal areas.

To obtain an indication of the chemical diversity of the groundwaters in the Hamelin Pool and Lharidon Embayment coastal areas, groundwater survey samples were collected at a . umber of locations, and a tentative assessment of their origins was made on the basis of chemical data. This information is summarised in Tables B4 and B5. Clearly the artesian water from the Hamelin Station bore-hole and the dune water from Booldah Well are mainly non-marine water. Continental-water influence is also evident at the landward margin of the supratidal zone at Petit Lagoon (S=30°/oo) and at Flagpole Landing (S=30°/oo), and over a zone extending from near the middle of the supratidal zone to beneath the beach ridges at Nilemah Embayment. Water from beneath the dunes at Nilemah Embayment has high Ca/Cl, Sr/Cl ratios and is the least saline of groundwaters along a transect extending to Hamelin Pool (Figure B3). The origins of the groundwater at the base of the dunes at the Playford site are not clear. The Sr/Cl ratios of the waters are about 20% higher than that of Hamelin Pool seawater, but a difference of this magnitude may not be significant. The origins of the water in the Solar Ponds (Fig. B2) and at Flagpole Landing are discussed elsewhere in this report by L.A. Plumb.

At Nilemah Embayment a combination of broad intertidal and supratidal flats and marine and continental groundwater input has allowed the two groundwater types to evolve through a number of chemical stages before they meet and mix near the middle of the supratidal zone. When seawater is concentrated by evaporation a small quantity of aragonite is precipitated and then, at salinities about 4 x SW, gypsum starts to precipitate. This sequence occurs in surface seawater samples evaporating in tidal ponds in the Hamelin Pool and Lharidon Bight, and, in these areas, gypsum precipitation starts at salinities close to the predicted value. The Ca and SO_4 concentrations in the incoming continental groundwaters at Nilemah are sufficiently close to those of normal seawater for their predicted gypsum precipitation point to be close to that of normal seawater. However, when the actual Ca and SO_4 concentrations in groundwaters along the Nilemah transect are compared to those predicted for evaporating seawater it becomes apparent that there are major discrepancies (Fig. B4).

These discrepancies are of two types: (1) areas along the transect where Ca and SO_4 are lost from the waters in nearly equivalent proportions, but the $aCa^{2+} \times aSO_4^{2-}$ product is below that necessary for saturation with respect to gypsum ($A + A^1$, Figure B4) and (2) areas where the waters have acquired excess SO_4 but not an equivalent excess of Ca (B and B^1, Figure B4). At present, the processes involved are not definitely known, but possible explanations can be given.

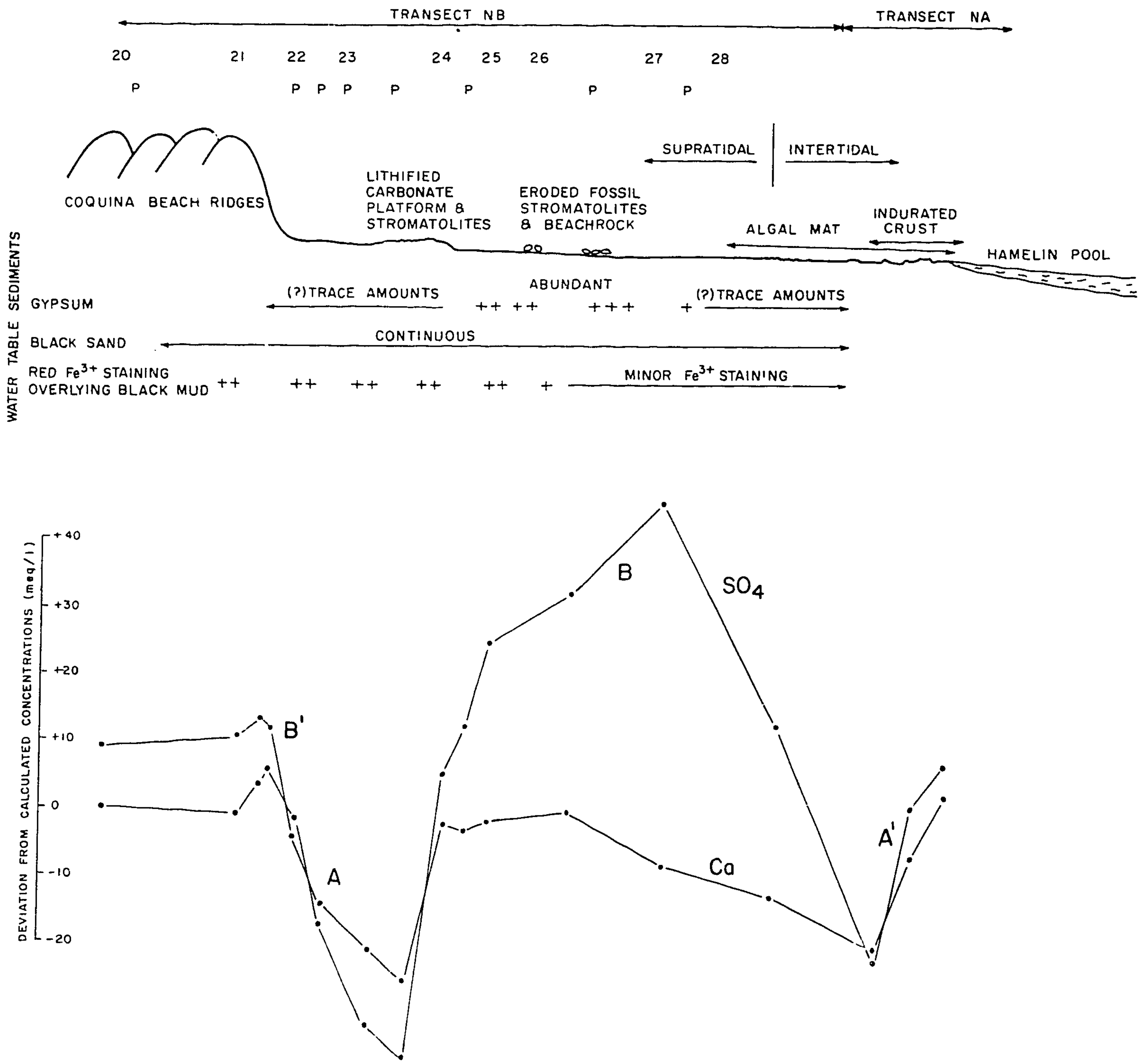

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Fig. B4 DEVIATIONS OF Ca AND SO_4 CONCENTRATIONS FROM THOSE PREDICTED FOR EVAPORATED SEAWATER WITH GYPSUM PRECIPITATION COMMENCING AT SALINITY 4·0 X SW

TABLE B4

CHEMICAL PARAMETERS OF SEAWATER AND LOW-SALINITY METEORIC AND ARTESIAN GROUNDWATERS FROM HAMELIN POOL

Location	Probable Origin	S°/oo	pH	Alkalinity (meq. l^{-1})	Weight ratios x 10^2					
					Ca/Cl	Sr/Cl	Na/Cl	K/Cl	Mg/Cl	SO_4/Cl
Well in coquina beach ridge (Booldah Well)	Meteoric	11	8.49	5.9	7.8	0.87	73	5.0	6.8	17
Borehole, Hamelin Station	Artesian	5	6.70	4.1	6.1	0.10	75	3.4	7.7	24
Hamelin Pool, Nearshore Surface water	Marine	78*	8.06	3.0	2.1	0.043	58	2.1	6.3	14

* Salinities 55-70 °/oo are typical

TABLE B5

CHEMICAL PARAMETERS AND PROBABLE ORIGINS OF GROUNDWATER SURVEY SAMPLES FROM HAMELIN POOL AND LHARIDON BAY

Location	Probable Origin	S°/oo	pH	Alkalinity (meq. l^{-1})	Weight ratios x 10^2 Ca/Cl	Sr/Cl	Na/Cl	K/Cl	Mg/Cl	SO_4/Cl
Saline water beneath Coquina dunes, Nilemah Embayment (NB 20.14)	Meteroic component	33	7.58	2.9	2.8	0.18	56	2.2	5.7	12
Water from beneath lithified crust at base of dunes, Petit Lagoon (LBN)	Meteoric component	30	7.81	2.2	2.7	0.06	59	2.1	6.2	14
Water from base of dunes at Playford site (PA11)	Possible meteoric component	60	7.23	4.8	2.3	0.05	62	2.1	6.3	14
Water from base of dunes on Solar Ponds Transect (BH 31.16)	Possible meteoric component	73	7.35	2.8	2.0	0.05	59	2.1	5.9	12
Water from beneath lithified pavement at landward edge of supratidal zone, Nanga Lagoon (LBS1)	Marine	58	7.68	1.7	2.1	0.04	61	2.1	6.3	14
Water from area of high discharge at base of dunes, Flagpole Landing	Meteoric and artesian	30	7.62	3.2	3.2	0.18	64	2.6	6.0	23
Near-shore, surface seawater, Hamelin Pool	Marine	78	8.06	3.0	2.1	0.04	58	2.1	6.3	14

The broad area of high SO_4 concentrations at B^1 corresponds approximately to the area where the sediments contain large quantities of gypsum. Presumably, the high SO_4 concentrations result from dissolution of sedimentary gypsum when the waters become temporarily undersaturated with respect to gypsum after an influx of tidal or continental floodwater. The lack of an equivalent increase in Ca may result from the precipitation of aragonite. However, precipitation of the amount of aragonite involved seems to require that the carbonate alkalinity available in concentrated Hamelin Pool seawater be supplemented by alkalinity generated within the sediments by, for example, bacterial sulphate reduction. The approximately equivalent decrease of Ca and SO_4 in zones A and A1 suggests that gypsum has precipitated from the groundwaters and marine brines at these locations. Most likely the water chemistry reflects a period when the incoming groundwaters were more saline. This period could have been followed by an influx of lower-salinity continental water or by normal seawater which at the time of sampling had not had time to re-equilibrate with gypsum in the sediments. In interstitial waters of sabkhas of the Persian Gulf, gypsum precipitates at about 3.4 x SW salinity, which is lower than the value of 4 found for the surface marine brines of Hamelin Pool and Lharidon Bight, but is higher than the lowest value of about 2.5 x SW at which Ca and SO_4 concentrations start to decrease in the Nilemah groundwaters.

PRODUCTION AND FATE OF ORGANIC CARBON IN BENTHIC CYANOBACTERIAL MATS

by

J. Bauld & L.A. Plumb

STAFF: J. Bauld, L.A. Plumb, H.M. Thomas, G. Trengove.

Cyanobacterial (blue-green algal) mats are associated with the intertidal areas of northeastern Spencer Gulf (Fig. B5). Filamentous cyanobacteria preferentially colonise sediments in slight topographic lows where water is retained for long periods after inundation at high tide. The mats are composed of a 1-2 mm layer of living cyanobacteria which overlies black sediments where active sulphate reduction occurs. There are three morphologically distinct mat types each constructed by a different filamentous cyanobacterium. The two mat types used in the work reported here are referred to as smooth mat (constructed by *Microcoleus* sp.) and tufted mat (constructed by *Lyngbya* sp.).

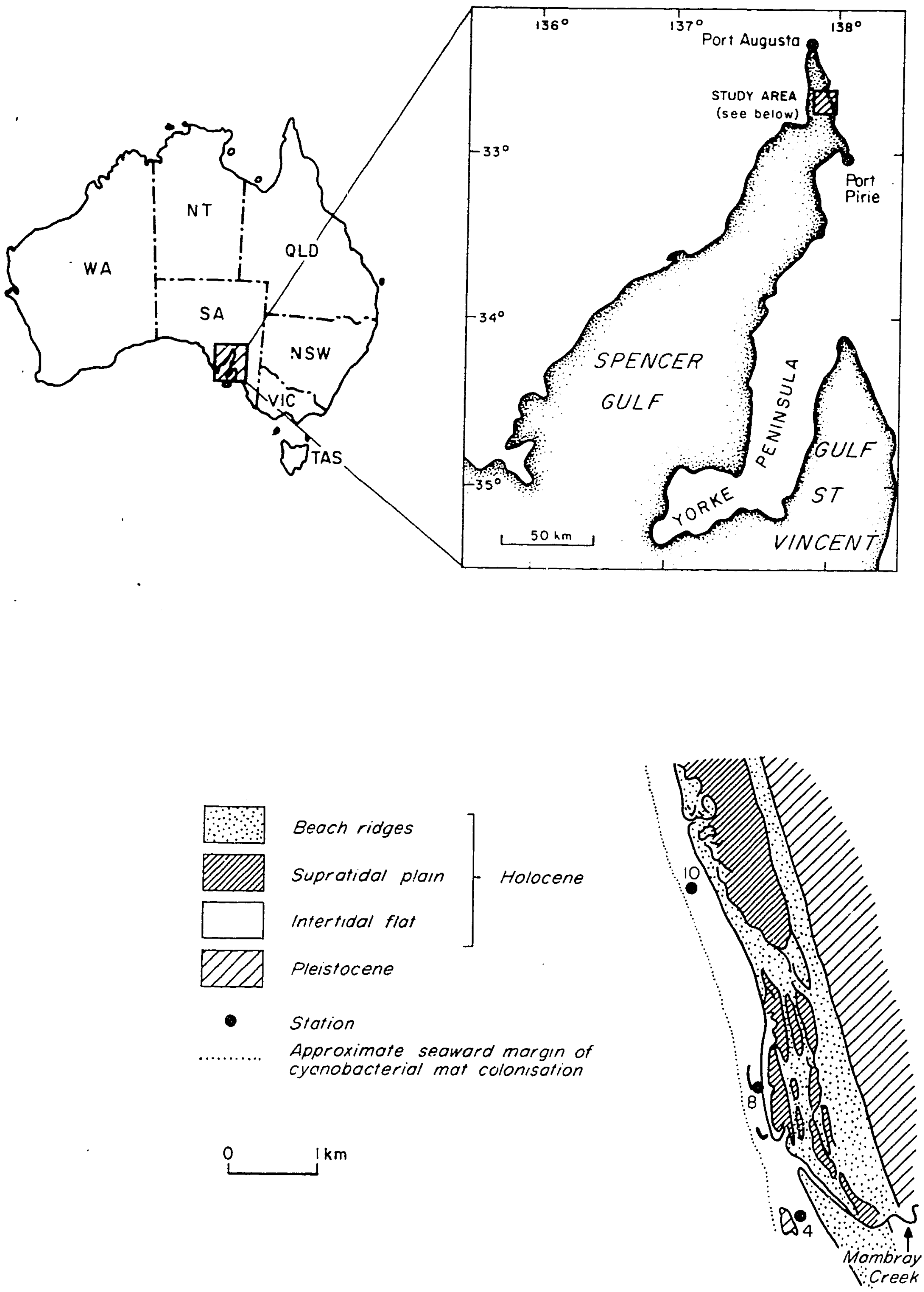

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Fig B5 Location of study area in northeastern Spencer Gulf.

The dependence of bacterial sulphate reduction and other heterotrophic processes on cyanobacterial primary productivity is indicated by the observations that photosynthetically active mat supports higher sulphate reduction rates than does inactive mat and that the most rapid sulphate reduction rates occur immediately below the living cyanobacterial mat. Other major organic inputs appear to be lacking in the higher intertidal environment.

It is in this context that the partitioning of photosynthetically fixed CO_2-carbon between cyanobacterial biomass (Particulate Organic Carbon = POC) and soluble, excreted compounds (Dissolved Organic Carbon = DOC) assumes considerable significance. While utilisation of POC is delayed because of the requirement for decomposition and solubilisation before becoming available as substrate, DOC provides a potential source of immediately available organic carbon for heterotrophic uptake (Fig. B6).

This project continues to be supported by AMSTAC and, since its inception, has proceeded along the several independent lines of research listed below:

* Field experiments to determine
  (a) the proportion of photosynthetically fixed $^{14}CO_2$ subsequently detectable as $DO^{14}C$.
  (b) the effect of environmental factors such as light and salinity of $DO^{14}C$ excretion.

* Field and laboratory studies of $DO^{14}C$ distribution in cyanobacterial mat sediments and the spatial relationship to sulphate reduction.
* Axenic culture of representative mat-constructing cyanobacteria for laboratory experiments.
* Work-up of preparative and analytical procedures for identifying and quantifying of DOC components.

SUMMARY

1. During field experiments in which intertidal cyanobacterial mats were incubated with $^{14}CO_2$ the proportion of photosynthetically fixed carbon subsequently detectable as $DO^{14}C$ was usually ca 1-3%, occasionally as high as 5%, and frequently less than 1%. These are similar to values reported for hot-spring mats(3-10%) and <u>Phormidium</u> mats from an Antarctic freshwater lake (0.4%).

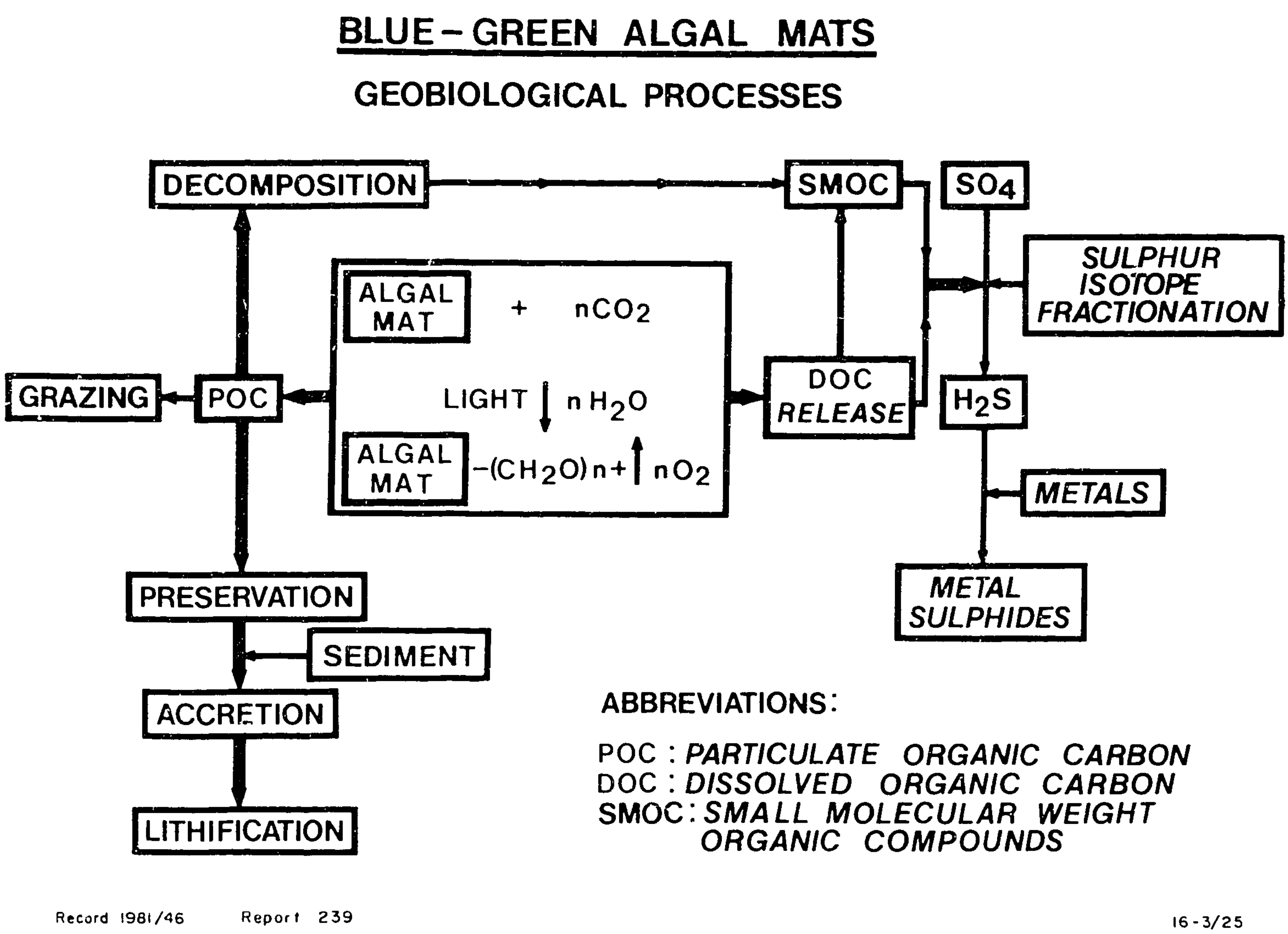

Fig B6 Flow diagram of processes occurring in blue-green algal (cyanobacterial) mats, showing the interdependence between biological, sedimentological, geochemical and hydrological phenomena.

2. $DO^{14}C$ production was increased only at very high (ca 120°/oo) or very low (2°/oo) salinities, in which it rose to values of 5-6% of photosynthetically fixed carbon (e.g., Table B6).

3. Variations in light intensity have no detectable effect on DOC production by smooth mat. To some extent this conclusion was due to the very low % DOC detectable (<0.005%).

4. Detectable $DO^{14}C$ was also very low during recovery from desiccation. This may be due to tighter metabolic control and increased retention of DOC within the cell during the recovery period, and consequent direction of DOC or potential DOC into POC.

5. In laboratory mat systems the % $DO^{14}C$ increases at lower sulphate levels and presumptive lower demand via depressed sulphate reduction rates (see Table B7).

6. A preliminary experiment suggested that metabolic inhibitors might be usefully employed in the investigation of DOC pools and fluxes. The potential of inhibitors such as DCMU and non-metabolisable analogs such as fluorolactate should be further examined.

7. The information we have obtained so far suggests the following as our working hypothesis:

The measurable or detectable DOC pool is small, and the flux of organic carbon through it rapid, relative to POC. The DOC pool is utilised by a variety of heterotrophs including sulphate-reducing bacteria. The heterotrophic sink for DOC is tightly coupled, both physically and metabolically, to the cyanobacterial component producing the DOC.

The tenacity of the heterotrophic contaminants in our cyanobacterial cultures, the relatively low % DOC values compared with planktonic systems, and the increase in detectable DOC under low sulphate concentrations are indirect evidence which is consistent with a tightly coupled system exhibiting rapid transfer between a phototrophic source and heterotrophic sinks via DOC.

The potential use of experimental tools such as the metabolic inhibitor DCMU to measure ^{14}C label loss from the $DO^{14}C$ pool in the absence of production, and non-metabolisable substrate analogs to measure $DO^{14}C$ accumulation in the absence of utilisation, should assist in obtaining more accurate information about DOC pool sizes and fluxes.

TABLE B6

EFFECT OF SALINITY ON PHOTOSYNTHETIC $^{14}CO_2$ FIXATION BY SMOOTH MAT AND ITS PARTITIONING INTO $PO^{14}C$ AND $DO^{14}C$

Salinity (°/oo)	POC*	DOC*	Σ(POC=DOC)*	DOC / Σ (%)
12	216678	792	217470	0.003
51	142978	3199	146177	2.2
123	46123	2921	49044	6.0

*CPM per core.
Incubation temp. 23-27°C. Incubation time, 120 mins. Light intensity, 1200-2200 μE $m^{-2}s^{-1}$; mostly 1800-2000 but fluctuating.

TABLE B7

PRODUCTION OF ORGANIC CARBON IN LABORATORY-GROWN MAT AND PARTITIONING BETWEEN $PO^{14}C$ AND $DO^{14}C$

	Productivity $mgCm^{-2}h^{-1}$	Distribution % POC	DOC
Plus sulphate			
Light	50	94	6
Dark	18	33	67
Control			
Light	30	85	15
Dark	6	50	50

SEDIMENTOLOGICAL STUDIES OF LAKE ELIZA, SOUTH AUSTRALIA

by

R.V. Burne

STAFF: R.V. Burne, J. Ferguson and M. Tratt.

Lake Eliza is one of three coastal lakes northeast of Robe, South Australia. It lies in an interdune hollow, in a similar setting to the Coorong Lagoon, but has no direct connection with the sea. Preliminary studies of the lake were made during February to establish its suitability as an area for the study of carbonates, evaporites, sulphide formation, groundwater-sediment interactions, and the accumulation of organic material.

The presence of marine molluscs in near-surface sediments indicates that the Lake has recently been in direct connection with the sea, but its present isolation enables the lake level to fluctuate seasonally. In summer the lake contracts in area, and peripheral deposits of halite form. Windrows and berms left behind by the retreating lake waters contain different organic materials which reflect the progressive increase in salinity in the retreating lake waters.

The lake shores are marked by areas of groundwater seepage from various sources, and the geochemistry of these waters, coupled with the physiographic setting of the shore gives rise to two contrasting types of lake margin.

The southeastern margin is sheltered; prevailing winds blow offshore. Extensive areas contain numerous groundwater springs. Algal mats are not well developed on the surface, but a thick, jelly like sequence of organic matter, presumably of algal origin, underlies the surface. Evaporites are interleaved with the organic laminations which also contain sulphide framboids. Samples of this organic matter are being examined petrologically to establish whether it is a recent analogue of a lamosite, or laminated oil shale.

The northwestern shore is, in contrast, exposed to wind-generated wave attack, and is dominated by cross-laminated and cross-bedded sands.

Deposition of halite from summer, highly saline lake waters is concentrated on this side of the lake. Diagenetic features of the sandy flat exposed at low lake level include enterolithic veins of gypsum and platy, carbonate-lithification of the sand. Groundwater seepage forms extensive marshes along this shore, and the interaction of these waters with lake waters may be responsible for the observed diagenetic effects.

The combination of carbonate sedimentation, evaporite deposition, organic sediments, and diagenetic features indicate that further study of the area is merited.

IRON AND THE FIXATION OF SULPHIDES IN MODERN SEDIMENTS

by

P.A. Trudinger

In earlier studies in this Laboratory we concluded that rates of bacterial sulphate reduction in many modern sedimentary environments are of the same order as those of sulphide deposition calculated for a number of base-metal sulphide deposits (Trudinger & others, 1972)[1]. Such deposits include the Kupferschiefer (Mansfeld), Roan Antelope, McArthur (HYC), and Mount Isa.

This conclusion is supported by recent determinations of sulphate reduction rates in the intertidal sediments of Spencer Gulf (see Baas Becking Annual Report, 1980)[2] and in several shallow-water coastal sediments studied by overseas scientists.

A survey of the literature, however, reveals that most unconsolidated detrital and bioclastic reducing sediments contain only low concentrations of fixed sulphide: maximum values are generally below 1.5-2%S and mean values are below 1.0%S (Fig. B7). These concentrations compare reasonably well with those of relatively low-grade ores like Kupferschiefer (av. 3%S) and Roan Antelope (av. 1.1%S), but are an order of magnitude below those of high-grade ores such as the McArthur HYC (14%S) and Mount Isa (12%S) deposits.

A major limitation on the fixation of biogenic sulphide in sediments is the supply of reactable metals. Nevertheless, there are a few reports that potentially reactable iron (acid extractable) exceeds the amount fixed as sulphide even in sediments (e.g., Black Sea) that are permanently overlain by hydrogen sulphide-containing waters.

A considerable excess of acid-reactable iron over fixed sulphide was found in all but one of 15 samples from the reduced sediments of Gladstone Embayment, Shark Bay (WA): Fe/S values ranged from 1.2 to 13.6 with an average of 5.4 and a standard deviation of 2.9.

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[1] Economic Geology, 67, 114-27.

[2] Also in BMR Report 230.

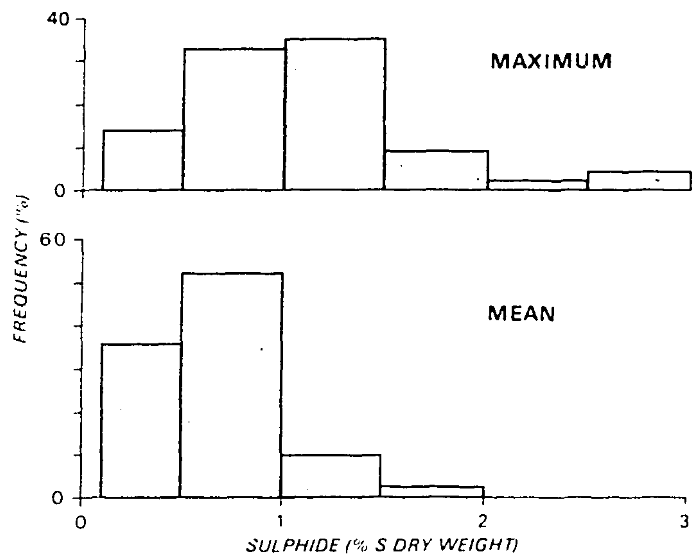

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Fig. B7 Frequency plots of mean and maximum values for fixed sulphide in unconsolidated, reduced marine sediments (sediments containing an average of less than 0·1% sulphide not included).

Data from: Black Sea, Baltic Sea, Great Bay Estuary, NH, Gulf of California, Californian offshore basins, Cariaco Trench, Pacific Ocean, Long Island Sound, Limfjorden, Solar Lake, Pedernales, Venezuela, Indian Ocean and Moroccan Basin.

Studies have been undertaken to determine the total amount of H_2S-reactable iron in sediments by exposing samples to an atmosphere of H_2S for various times. Preliminary results with material from Spencer Gulf and Shark Bay indicate that, within the active zone of sulphate reduction, the amount of potentially H_2S-reactable iron exceeds that actually fixed as sulphide in situ.

Further work is necessary to determine the reasons for the non-reactability of iron in the in situ system.

SULPHATE REDUCTION RATES IN SEDIMENTS FROM HAMELIN POOL, GLADSTONE EMBAYMENT AND NILEMAH EMBAYMENT, WESTERN AUSTRALIA

by

G.W. Skyring

STAFF: G.W. Skyring, L.A. Plumb, M.H. Reed.

Sulphate reduction rates in cyanobacterial mat-associated sediments of the hypersaline environments in Hamelin Pool (WA) were similar to those found in cyanobacterial sediments from Spencer Gulf (SA). In some intertidal locations on the shores of Hamelin Pool, there are deposits of sediments which, when forming, contain a large quantity of organic material which was dislodged from intertidal and subtidal columnar stromatolites by tidal waters. These sediments are characterised by high sulphate reduction rates and $\delta^{34}S$ ratios which suggest a partly closed system with respect to sulphate (Bauld & others, 1979)*.

In November 1980, sediments of the latter kind were found in the area now known as Playford's transect and in the same area as that studied by Bauld & others (1979). These black, reducing sediments extended landwards of the high-tide line and were covered by loosely packed shelly material of a prograding beach ridge. The sulphate reduction rates in the black sediments were 7.7 ± 3.9 mmol $m^{-2}d^{-1}$ or 285 ± 169 nmol $g^{-1}d^{-1}$ (n=12). The sulphide concentration was 59 ± 28 μmol g^{-1}. With respect to sulphate reduction rates in marine environments, these are quite high. The sulphate reduction rates were lower than those (1000 to 500 nmol $m^{-2}d^{-1}$) found in similar sediments by Bauld & others (1979). The sulphide concentrations were also similar to those (34 to 88 μmol g^{-1}) found by Bauld & others (1979).

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* Australian Journal of Marine and Freshwater Research, 30, 753-64.

Sulphate reduction rates were also determined for laminated carbonate sediment from Gladstone Embayment. The sediments were colonised by cyanobacterial mat and were covered by tidal waters. The sulphate reduction rates, sulphide, and sulphate concentrations, and a brief description of the 0.20 cm layer, is given in Table B8. The sulphate reduction rates were highest in the 0-1 cm layer; below 5 cm the rates were very low. There was, however, a slightly higher sulphate reduction rate in the black laminated layer between 10 and 11 cm. Although these cyanobacterial mat-associated sediments from Gladstone Embayment were not exactly analogous to those in Solar Lake (Jorgensen & Cohen, 1977)[1] the pattern of sulphate reduction with respect to depth was very similar.

Sulphate reduction rates were also determined for sediments taken along surveyed transects at Nilemah Embayment. The rates were generally very low except for those found in the unconsolidated sediments at station 2, transect A. These rates (2 to 9 mmmol $m^{-2}d^{-1}$) were similar to those in sediments at Playford's transect. These, and previous studies in Hamelin Pool (Bauld & others, 1979) indicate that, in these stromatolite environments, there is translocation of large quantities of organic stromatolite debris. In areas where this organic material collects and becomes part of the sediment, high sulphate reduction rates are observed.

SPENCER GULF STUDIES: SIGNIFICANCE FOR MODELS OF STRATIFORM COPPER ORE GENESIS

by

James Ferguson & R.V. Burne

Stratiform deposits which lack evidence of either igneous or hydrothermal influence are important and globally widespread sources of copper. They presumably accumulated as a result of sedimentary and diagenetic processes operating at low temperatures, but the precise nature of these processes remains obscure, and commonly proposed genetic models actually contradict some characteristics of these deposits. Renfro (1974)[2] has proposed a model for copper ore formation which depends upon processes operating in environments such as those found in the coastal sabkhas of the Persian Gulf or the Gulf of California. This model requires the mobilisation and transport of trace

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1 Limnology and Oceanography, 22, 657-66.

2 Economic Geology 69, 33-45.

TABLE B8

SULPHATE REDUCTION RATES AND OTHER CHARACTERISTICS OF CYANOBACTERIAL MAT ASSOCIATED SEDIMENTS OF GLADSTONE EMBAYMENT, WESTERN AUSTRALIA

Sediment type	layer cm	Sulphate concentration in porewater mM	Sulphide concentration $\mu mol\ g^{-1}$	Sulphate reduction rates $nmol\ g^{-1} d^{-1}$.
cyanobacterial mat, black	0-1	89	49	1880
black	1-1.5	87	45	292
grey	1.5-3.0	89	24	96
black	3-4	87	32	79
black	4-5	89	93	157
black	5-5.5	98	44	88
grey	5.5-7	81	49	20
black	7-8	78	26	3
black and grey	8-9.5	84	20	2
black and grey laminated	10-11	84	19	150
"	11-12	107	13	3
"	12-13	103	13	4
shell fragments, grey	13-15	95	9	2
laminated black and grey	15-17	95	4	0
grey	17-18	95	6	3
laminated black	18-20	101	25	3

amounts of copper, silver, lead, and zinc from continental redbeds by low-salinity terrestrial formation waters of low pH and high Eh. On reaching the coastal zone these waters interact with organic-rich intertidal sediments which were formed during a marine transgression from deposits of algal mats and then buried by supratidal evaporites after subsequent marine regression. The metal-bearing waters react with dissolved sulphide formed by microbial sulphate reduction in the organic-rich layers and metal sulphides are formed which are zoned seawards according to their relative solubilities. This model explains the internal zonation of stratiform deposits and their setting between underlying oxidised strata and overlying evaporites.

Rose (1976)[1] has shown that low-salinity waters are relatively ineffective in transporting dissolved copper, as the solubility of copper at likely pH values is less than 1 ppm. Much higher solubilities are possible in chloride-rich brines because the cuprous ion is able to form the complex ions $Cu\ Cl^-$ and $Cu\ Cl^{2-}$. Rose concluded that, unless the terrestrial formation waters of Renfro's model were saline, copper would not be sufficiently soluble in them to give rise to appreciable deposits.

No strictly analogous present-day environment of copper concentration has been described but the northeast coast of Spencer Gulf is an appropriate place to test the feasibility of some aspects of these models. The coastal sediments of the area have a depositional setting similar to that of sediments associated with many stratiform copper deposits. The area is a rich copper province (but the Proterozoic sediments adjacent to the northeastern shore of the Gulf are not extensively mineralised and are composed dominantly of quartzites). The gulf south of Port Pirie is flanked by a piedmont plain consisting of alluvium and Pleistocene aeolian dunes. The sediments of these plains are Quaternary redbed sediments which, at the shoreward margin, consist of yellow-brown or red-brown, quartz-rich clayey sands and sandy clays containing secondary carbonate (e.g., Colwell & Burne, 1978)[2].

The area experiences a semi-arid climate, and surface drainage is limited. However, there is active groundwater movement through aquifers of the piedmont plain from areas of recharge in the higher rainfall areas of the hills to areas of groundwater discharge in the coastal zone. There, they interact with sediments that have been deposited during the Holocene transgressive and more recent regressive phases. These sediments include carbonates and evaporites, as well as organic sediments formed from intertidal cyanobacterial

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1 Economic Geology, 71, 1036-48.

2 BMR Record 1978/88.

mats in which bacterial sulphate reduction is locally active. The continental groundwaters are generally acid, saline, and oxidising, and they mobilise Fe and Mn from the redbed aquifer sediments and transport them to the Holocene carbonate complexes where they may precipitate in sediments in ephemeral lakes or around groundwater springs.

The major shortcoming of Spencer Gulf as a potential analogue for ancient copper ore-forming environments is the lack of readily leachable metals in the redbed sediments of the coastal-plain aquifers. This may be due to the absence of rich metal sources in the provenance quartzites of the Flinders and Barunga Ranges. Total Cu concentrations in the finer-grained Quaternary redbed sediments are comparable with the 15 ppm which Rose (1976) suggested was adequate for the generation of an ore deposit, but they may occur in relatively inaccessible sites within the sedimentary grains and not associated with the iron oxide grain coatings.

The hydrology of the Spencer Gulf coastal plain is similar to that suggested by Renfro (1974) for his model. The semi-arid climate and significant topographic relief of Spencer Gulf would lead to a considerably greater groundwater flow rate than would be experienced in an arid region of low topography such as that invoked by Renfro, but residence times of groundwaters in the confined deeper aquifer systems may be similar to those of Renfro's model coastal plains.

The groundwaters of the Wood Point and Fisherman Bay areas generally have chlorinities greater than the 0.5M suggested by Rose for the optimum generation of high Cu solubilities. It is unlikely that high Cu concentrations could be generated at the extremes of the wide range of Eh and pH values found in these waters. However there are groundwaters between these extremes with a combination of chlorinity, Eh, and pH that would permit the solution of Cu in sufficient concentrations for them to be effective ore-forming solutions.

It has been suggested that groundwaters mobilise metals from the iron oxide grain coatings of the redbed aquifer sediments either as a result of originally hydrated iron oxide phases such as goethite converting to hematite and expelling metals into solution (Rose, 1976), or as a result of iron oxides being dissolved as Fe (III) and reduced to FE (II) within the aquifer system (Renfro, 1974). No evidence has been obtained for the former process, but dissolution of Fe is widespread in the aquifer systems of Spencer Gulf, and in the deeper sediments it is efficient enough to generate groundwater Fe concentrations comparable to those associated with volcanic exhalations.

The fact that metal sulphides in stratiform deposits are zoned according to their solubility products implies that both metals and sulphides were in solution immediately before the formation of metal sulphides. This suggests a direct, relatively rapid interaction of metal-bearing saline terrestrial groundwaters and H_2S-bearing porewaters. Conditions in the coastal areas of Spencer Gulf unfortunately do not favour this process. Many of the sites of groundwater discharge do support a population of cyanobacteria which are a source of carbon for subsequent sulphate reduction, but the main areas of sulphate reduction are in the cyanobacterial flats and marshes of the high intertidal zone which usually lie some distance from the zones of groundwater discharge.

Unlike the model proposed by Renfro, the landward margin of the Holocene transgressive/regressive sequence does not preserve organic remains of former intertidal cyanobacterial mat, and therefore is not an area of widespread bacterial sulphate reduction.

Metal sulphide formation is also limited by the incompatibility of the mildly oxidising groundwaters with the strongly reducing conditions required for bacterial sulphate reduction. Thus sulphate reduction may be completely inhibited locally or seasonally around zones or groundwater discharge, but, with increasing distance away from the spring source or during seasonal decreases in flow rate, bacterial sulphate reduction becomes established.

The examination of Spencer Gulf coastal environments has demonstrated the feasibility of some aspects of proposed models of ore genesis: terrestrial groundwaters capable of transporting high concentrations of Cu, Pb, and Zn are generated within continental redbed sediments of semi-arid climatic zones; groundwater-sediment interactions within the redbed aquifers are capable of mobilising extensive quantities of metals from iron oxide grain coatings; and there are no obvious reasons why the hydrochemical conditions of the Spencer Gulf aquifer systems could not occur in areas where iron oxides of the redbeds were derived from the weathering of small quantities of sulphides in metalliferous granitic or basaltic rocks and were rich in Pb, Zn, or Cu.

The formation of a stratiform metal deposit that is zoned in accordance with metal sulphide solubilities is more difficult to envisage from the evidence of the Spencer Gulf coastal environments. The areas of coastal groundwater discharge are closely analogous to the inferred environment of formation of many stratiform copper deposits. They occur at the junction of continental redbeds and peritidal carbonate complexes which have been deposited during a Holocene transgressive/regressive cycle. These sediments are, in places, overlain by evaporites (mainly gypsum) and, in order to satisfy the requirements of Renfro's model would require only that the transgressive sequence be the site of preservation of a thick deposit of organic matter capable of supporting active sulphate reduction. In the absence of such deposits in the areas of groundwater discharge it is likely that metals transported by the groundwaters would be removed from solution by oxidation, absorption, and precipitation as oxides/hydroxides or carbonates. These metal species could later be converted to sulphides if the nature of the groundwater discharge changed to one which supported sulphate reduction, but the resultant sulphide deposit would have a zonation which would reflect processes other than sequential sulphide precipitation.

SIMULATED SEDIMENTARY SYSTEMS

by

B. Bubela

STAFF: B. Bubela, G. Jemmett and P. Philp.

The objectives of the simulated sedimentary system and the results for the previous 12 months have been described in detail previously. Since then the studies have concentrated on diagenetic processes affecting organic matter in the sediments.

As reported previously, organic matter isolated from the individual strata of the sediments was separated into hydrocarbons, alcohols, and organic acids. The following changes due to diagenetic processes were observed in the isolates.

The organic material introduced into the simulated sedimentary systems was of algal origin. The results of the organic analysis have shown the dominance of n-C_{17} hydrocarbon.

The dominant chemical characteristics of the algal material gradually decreased during the time of burial of the material in the sediments, while higher hydrocarbons increased in concentration. This change in hydrocarbon distribution was due to the formation of a secondary biomass of bacterial origin.

When after 2 years of burial the organic material was exposed to further biological activity at 60°C, alkenes, phytene isomers, phytane, pristane, a number of branched and cyclic hydrocarbons maximising in the C_{20} - C_{22} region, and n-alkanes in the range of C_{15}-C_{30}, appeared, with a predominance of odd over even hydrocarbons above C_{24} (Fig. B8).

A series of triterpenoids was also detected in the sample, but could not be analytically resolved by gas chromatography/mass spectroscopy techniques. A new component, 1,1 sulphonylbisbenzene, was detected in the material. At this stage it is not clear if its origin is biological or abiological.

A sample of the material which was exposed to diagenetic changes at 60°C was then exposed to anaerobic biological activity at 10 000 kPa. Analytical results indicated an increase in the intensity of the unresolved mixture of branched and cyclic hydrocarbons and a reduction in the C_{17} and C_{18} components which were dominant previously.

Comparison of the results obtained with the material exposed to diagenetic processes at room temperature and pressure has shown with increasing time, then with an increase of temperature and finally with a simultaneous increase of temperature and pressure, that the intensity of the analytically unresolved material increases quite considerably. The formation of such a material is strong evidence of bacterial activity and the gradual replacement of the original algal biomass by a secondary biomass of bacterial origin. The gradual masking and removal of algal characteristics in the newly formed material is indicative of the difficulties associated with deducing the original microbiological population in sediments that underwent diagenetic changes.

HYDROCARBONS

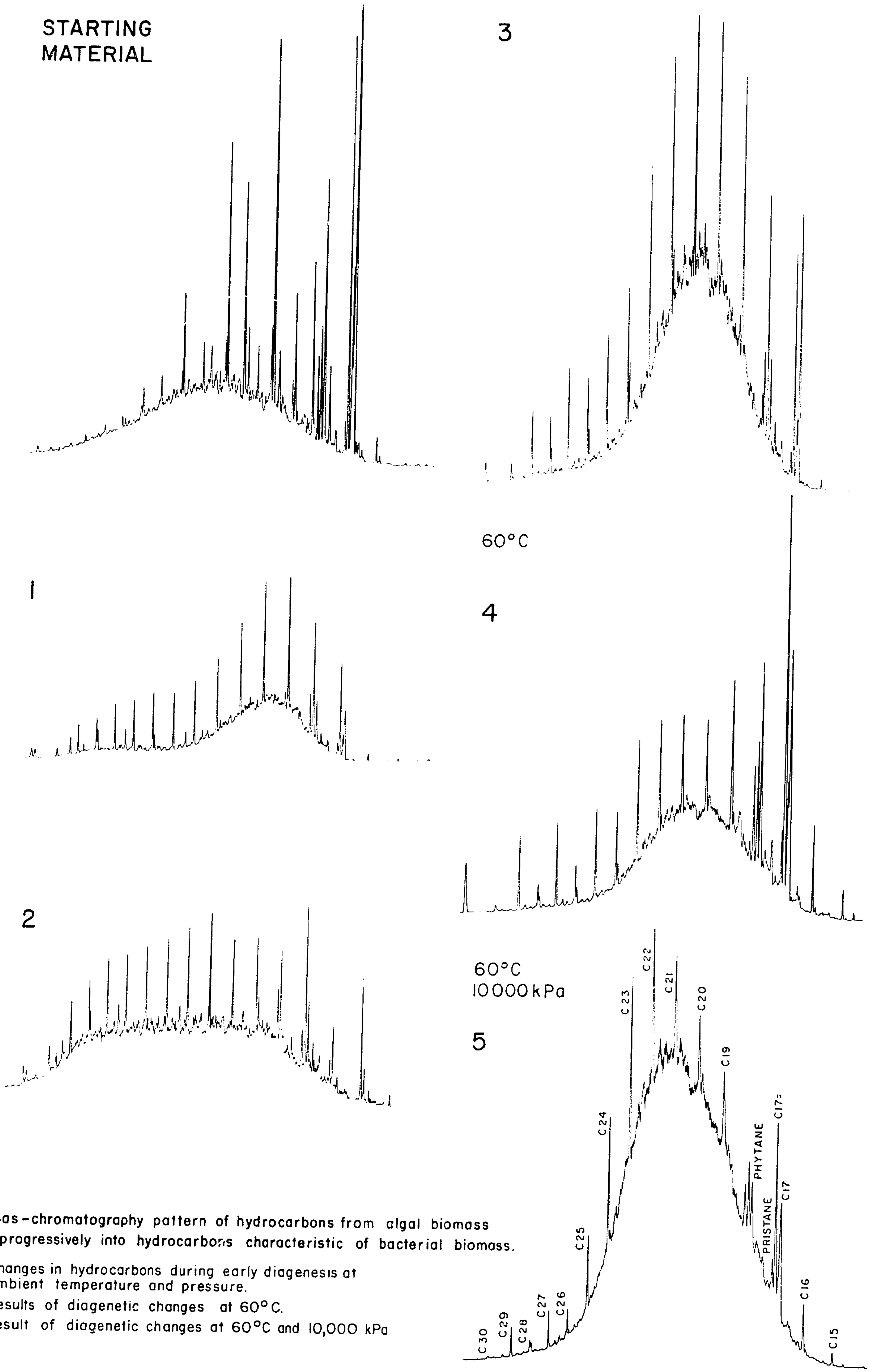

Fig. B8. Gas-chromatography pattern of hydrocarbons from algal biomass converted progressively into hydrocarbons characteristic of bacterial biomass.

1-3. Changes in hydrocarbons during early diagenesis at ambient temperature and pressure.

4. Results of diagenetic changes at 60°C.

5. Result of diagenetic changes at 60°C and 10,000 kPa

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THE EFFECT OF HEAVY METALS ON BIOLOGICAL SULPHATE REDUCTION

by

G.W. Skyring

STAFF: G.W. Skyring, James Ferguson, M.H. Reed and D. Fitzsimmons.

Experiments are being conducted to determine the sensitivity of sulphate-reducing bacteria to selected heavy metals in saline environments. Cultures of a halotolerant sulphate reducer were grown, to mid-log phase, in a defined medium which, in addition to the compounds required for growth, contained 8% NaCl. The pH of the cultures was lowered to pH 6.0 and the H_2S removed by sparging with O_2-free nitrogen. The pH was then readjusted to 7.0 and the effects of various concentrations of Cu, Zn, Pb, and Fe on the sulphate reduction rate were determined. In addition, the metal and phosphate concentrations in the medium were determined. The results of these experiments are given in Table B9. The concentrations of metals remaining in solution were lower than the concentrations added. The depletion was due to precipitation with (1) sulphide remaining in the culture after sparging, (2) the small amounts of sulphide produced during incubation, (3) phosphate, and (4) sulphate in the lead experiments. Copper and zinc affected sulphate reduction at concentrations around 20 μM (1.3 ppm) and above, and this was apparently due to phosphate depletion. Lead affected sulphate reduction at below detectable limits (by atomic absorption methods). The organism was far more tolerant to Fe. There was no detectable soluble phosphate in the growth medium with high iron concentrations and yet the sulphate reduction process was not completely inhibited. Thus it seems that the effects of the high concentrations of Cu, Zn, and Pb are due to the metal, not to low concentrations of phosphate.

TABLE B9

THE EFFECT OF VARIOUS CONCENTRATIONS OF Cu, Zn, AND Pb ON THE SULPHATE REDUCTION RATE OF HALOTOLERANT SULPHATE REDUCERS GROWING IN MEDIUM CONTAINING 8% NaCl

Metal concentration µM added	determined	Dissolved phosphate concentration µM	pH	Sulphate reduction rate µmol $ml^{-1}h^{-1}$
	Cu			
0 to 10	1.0 (.07)*	250	6.9 to 7.1	0.150
100	20.0 (1.4)	250	6.8	0.120
200	42.0 (2.7)	210	6.5	0.000
	Zn			
0 to 6	0 to 8 (.06)	280	7.0 to 7.2	0.150
10	20 (1.3)	280	7.0	0.008
510	250 (16.0)	145	7.0	0.00
	Pb			
0	0	350	6.9	0.120
50	0	350	6.9	0.100
250	0	130	7.2	0.060
450	17 (3.5)	10	7.2	0.000
	Fe			
0		-	7.5	0.130
1000 (56)		0	6.7	0.075
2000 (112)		0	6.7	0.050
3000 (168)		0	6.6	0.025
4000 (224)		0	6.7	0.024

* values in parenthesis are in ppm.

SULPHITE REDUCTION BY DESULFOVIBRIO VULGARIS

by

G.W. Skyring

STAFF: G.W. Skyring, M.H. Reed.

There is geochemical evidence that sulphate was present in some Archaean environments as long as 3400 to 3500 m.y. ago, and yet clear evidence for biological sulphate reduction in the S-isotope record of sedimentary sulphides and sulphates does not occur until about 2000 m.y. ago. Thus it seems to have taken an incredibly long time (ca 1500 m.y.) for dissimilatory sulphate reduction to have evolved among the Archaean procaryotes. One explanation for this is that the procaryotes of this time did not experience a selection pressure towards the utilisation of sulphate until about 2000 m.y. ago. Skyring & Donnelly (Precambrian Research, in press) have suggested that sulphite was a persistent component of the Earth's hydrosphere before 2000 m.y. ago, and that the evolution of biological sulphate reduction was initiated by the evolution of sulphite reduction.

It is possible that the persistence of sulphite in the Earth's anoxic hydrosphere delayed the development of a sulphate-reducing process among the evolving ancient procaryotes. In a series of experiments it was shown that even with a complete mechanism for the dissimilatory reduction of sulphate, *Desulfovibrio vulgaris* when growing in the presence of sulphate and sulphite will preferentially reduce sulphite to the exclusion of sulphate. It was also shown that, during the reduction of sulphite by *D. vulgaris*, thiosulphate is formed by the reaction of sulphide and sulphite. When the sulphite concentration reached a value of 1 mM the thiosulphate was then reduced to sulphide.

CULTURE COLLECTION OF SULPHATE REDUCERS

by

G.W. Skyring

STAFF: G.W. Skyring, M.H. Reed.

The collection is being checked against the original descriptions. This has not been done for 6 years. It is a tedious but necessary function for maintaining a reliable bacterial culture collection.

PRECAMBRIAN PALAEOBIOLOGY

by

M.R. Walter

STAFF: M.R. Walter & K. Cloud (part time)

During the year the results of research with the Precambrian Paleobiology Research Group at the University of California, Los Angeles, during 1979/80, were written up for publication. This work will be published by Princeton University Press as a multiauthored book which is now in press. A great amount of new palaeontological and geochemical information was gathered during this project, which concentrated particularly on Archaean and Lower Proterozoic sequences. The results were outlined in the Annual Summary last year (BMR Report 230).

A project that commenced in Los Angeles was continued during last year: that was the stable isotope geochemistry of the iron formations of the Hamersley Basin. This is being undertaken in cooperation with Prof. M. Baur (University of California) and Prof. J.M. Hayes (Indiana University). Results to date indicate systematic isotopic variations from microband to microband, such that the carbonates of iron-rich microbands are enriched in both ^{12}C and ^{16}O. Interpretations of this observation presently are speculative, but it suggests that seasonal climatic and microbial variations were recorded in the geochemistry of the deposited carbonates.

Searches for microfossils in the Cambrian Yelvertoft beds of the Georgina Basin and the Upper Proterozoic Albinia Formation of the Ngalia Basin have been successful, and the discovered microfossils are being documented. A search of the Upper Proterozoic Elkira Formation of the Georgina Basin, in cooperation with other members of the Georgina Basin Project and the Northern Territory Geological Survey, lead to the discovery of distinctive fossils that may prove to be useful index fossils. These are simple horizontal burrows, and ribbon-like possible higher algae.

PROTEROZOIC AND CAMBRIAN PETROLEUM

by

M.R. Walter

A major period of plate rifting commenced about one billion years ago, and lead to the formation of narrow depositional basins similar to those of the Cretaceous proto-Atlantic and Tethyan region. Within the Cretaceous basins, organic-rich sediments were deposited as a result of limited aeration of deep waters. These are the source rocks of some of the giant petroleum fields of the Middle East and elsewhere. The climatic, tectonic, and palaeogeographic conditions prevailing in the later Proterozoic and Cambrian in Australia and elsewhere seem to have been similar to those of the Cretaceous. Furthermore, during the Proterozoic there was no significant bioturbation owing to the lack of burrowing metazoans. Conditions would seem to have been ideal for the formation of unusually rich petroleum source rocks. Late Proterozoic black shales are known from the Adelaide Geosyncline, and Cambrian black shales occur in the Georgina Basin. At the same time, potential reservoirs were formed as extensive well-sorted sand bodies and abundant stromatolite reefs, bioherms, and biostromes. Evaporites occur at several stratigraphic levels and form potential cap sequences.

Organic matter in some of these sequences is known to be oil or gas mature, and indeed gas shows are known from the Late Proterozoic of the Amadeus Basin and oil shows occur in the Early Cambrian of the Officer Basin. Numerous oil and gas fields occur in Upper Proterozoic and Early Cambrian sequences in Siberia, and other occurrences are also known. All the indications are that Upper Proterozoic and Cambrian sequences in Australia are prospective for significant accumulations of hydrocarbons. Work is progressing on the development of these ideas as a working hypothesis to guide research on Upper Proterozoic and Cambrian sequences in Australia.

ORE GENESIS INVESTIGATIONS

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

STUART SHELF AND ADELAIDE GEOSYNCLINE

by I.B. Lambert, J. Knutson & T.H. Donnelly

STAFF: T.H. Donnelly, A. Juodvalkis, J. Knutson, I.B. Lambert, P.M. Ryan (until July).

Investigations continued in the Myall Creek and Copper Claim areas (Fig. B9), where we have been endeavouring to define metallogenic processes and exploration guides by assessing isotopic, geochemical, mineralogical, and petrographic features in the light of geological relationships. These have been carried out in collaboration with Seltrust and Utah Development Company, respectively.

MYALL CREEK

Copper mineralisation, with minor lead and zinc, is concentrated in unmetamorphosed carbonaceous dolo-siltstone and sandstone in the basal few metres of the Tapley Hill Formation. The main copper minerals are chalcopyrite, zincian arsenous tennantite, bornite, and chalcocite, which occur as disseminated grains and in irregular to straight veinlets. There has been some replacement of pyrite and other minerals.

Minor copper enrichments occur sporadically at the top of the unconformably underlying Beda Volcanics, which are brecciated and altered basic flows, and also at the top of the Tapley Hill Formation. There is a general decrease in Cu/Pb+Zn ratios inwards from both bottom and top contacts of the latter unit.

Other metals enriched in mineralised Tapley Hill Formation are Mn, Co, Ag, As, Bi, and Sn. The main mineralisation is surrounded by an extensive envelope of low-grade mineralisation, but no distinct geochemical or mineralogical halces have been found in unmineralised rocks.

The sulphur isotope compositions of the disseminated pyrite and base-metal sulphides are extremely variable and many are unusually ^{34}S-enriched with $\delta^{34}S$ values up to +40°/oo. These are interpreted in terms of biogenic reduction of isotopically heavy sulphate that was residual from earlier bacterial reduction in a basin with little replenishment of sulphate. Veinlet sulphides fall in the same range. Gypsum and anhydrite occurring in conformable layers and veins have $\delta^{34}S$ values near 20°/oo which indicate that they could not have formed from the same sulphate reservoir as the biogenic sulphide. This is in accord with textural evidence indicating that the early-formed evaporite minerals were dissolved out and the rocks partly filled by carbonate before the preserved sulphate minerals were introduced.

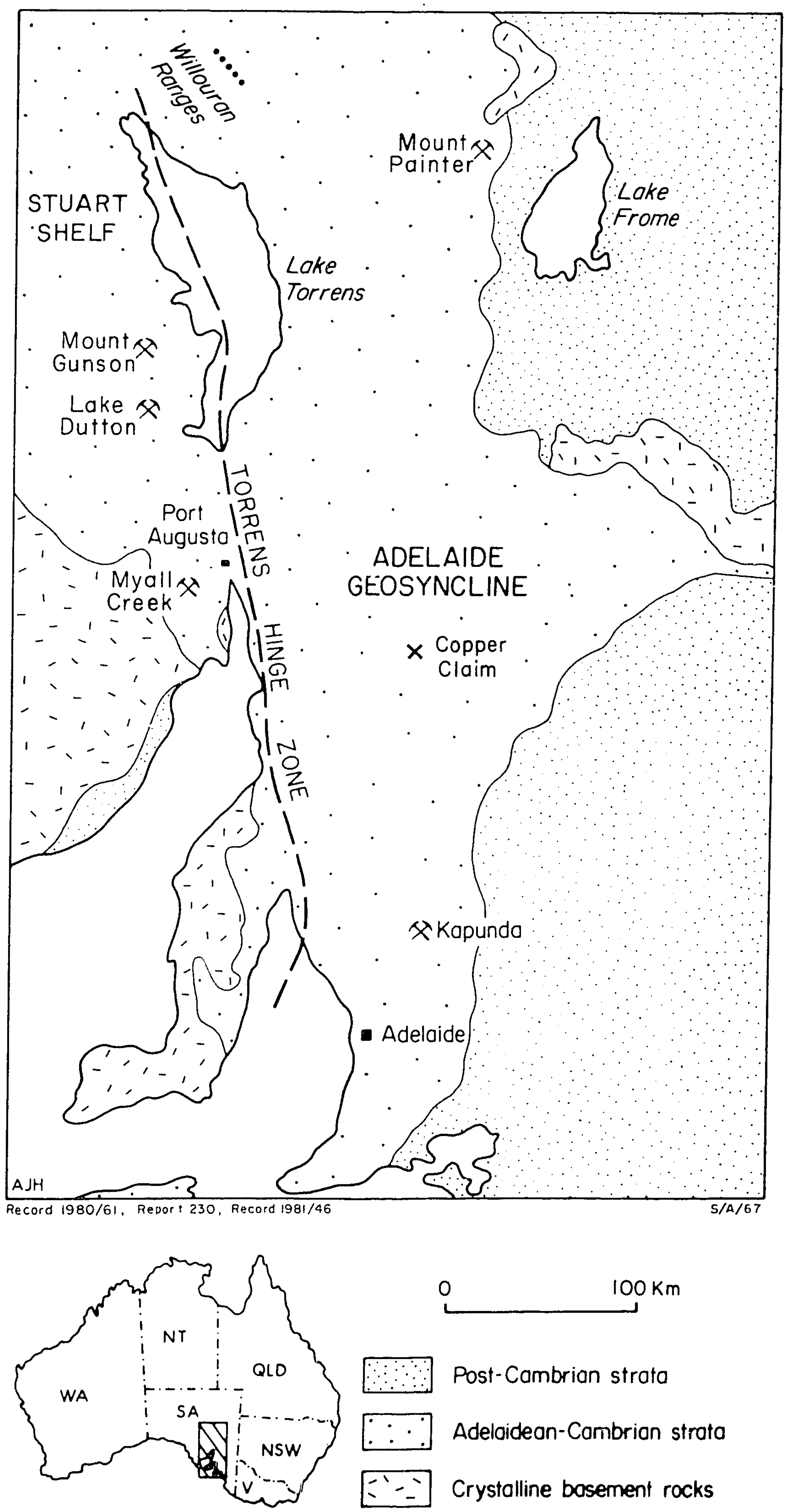

Fig. B9 Sketch map showing locality of the copper-rich areas under investigation, and major geological features of southern South Australia

$\delta^{13}C$ values for dolomite are between -2.5 and -4.5°/oo, suggesting some organic CO_2 was incorporated during sedimentation or diagenesis. $\delta^{18}O$(SMOW) values are close to +25°/oo in unmineralised strata and slightly above +26°/oo in mineralised rocks; they are within the normal range for Proterozoic carbonates.

Mineralisation in the Tapley Hill Formation is probably a function of (i) bacterial sulphate reduction in restricted environments; (ii) long-term influx of metalliferous brines via faults, basement contacts, and permeable strata; (iii) reaction of these brines with biogenically produced pyrite and H_2S in relatively permeable layers and microstructures; and (iv) partial remobilisation of disseminated sulphides.

COPPER CLAIM

Chalcopyrite and pyrite occur as fine to coarse-grained disseminations and coarse-grained veinlets within dolomitic and magnesitic siltstones, arenites, and pebble beds. Many of the veinlets are irregular and appear to have formed before complete lithification of the sediments. Furthermore, some rudite clasts contain sulphides, and some cross-bedded arenites contain sulphides that appear detrital. Geologists of Utah Development Co. have concluded that the sediments were deposited in lagoons and hypersaline sabkhas separated by sandbars from deeper-water environments, and they correlate them with the Callanna beds of the basal Adelaidean.

Disseminated and vein sulphides from the mineralised strata have $\delta^{34}S$ values in the range -12°/oo to +12.5°/oo, whilst sulphides from the hangingwall dolomite have values as low as -17.5°/oo. Interpreted in terms of geological features, they imply bacterial sulphate reduction whose sulphate source and/or conditions of reduction changed not far above the mineralised strata. The Copper Claim values are not as ^{34}S-enriched as the pyrite and copper sulphides from the younger Tapley Hill Formation at Myall Creek (above), Kapunda and Mount Gunson (cf. previous reports).

Bedded and vein carbonates from the mineralised strata have $\delta^{13}C$ values between -1°/oo and +7.5°/oo, and no systematic difference between dolomite and magnesite; hangingwall dolomite has $\delta^{13}C$ values as low as -9°/oo. $\delta^{18}O$ values for bedded dolomite and magnesite in the mineralised strata are in the range +15°/oo to +28°/oo with a concentration of values around +23°/oo. The vein carbonates have $\delta^{18}O$ values that are slightly lower, concentrating around +20°/oo.

The isotopic results imply formation of the bulk of the veinlets at low temperatures from components dissolved by connate waters from the mineralised sediments. Parts of the sediments were subsequently recrystallised by meteoric waters.

MOUNT PAINTER INLIER

by I.B. Lambert, T.H. Donnelly, & J. Knutson

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

Investigations of breccia genesis, in collaboration with John Drexel of the South Australian Department of Mines and Energy, have now been completed.

Field and petrographic studies on the granitic, hematitic, and chloritic breccias in the central portion of the Mount Painter Inlier indicate that (i) breccias and brecciated basement extend to depths exceeding 400 m and have gradational contacts; (ii) clasts are mainly autochthonous and contain fine-scale hematite, chlorite, or quartz in veinlets and fractures; (iii) K-metasomatism preceded hematitisation and chloritisation; (iv) hematitic breccia intrudes a pegmatite dyke correlated with the Ordovician Arkaroola Pegmatite; and (v) U, F, and REE-containing minerals are present in the Proterozoic basement rocks, and concentrated in the breccias.

With a single exception, $\delta^{34}S$ values for pyrite from the breccias and brecciated granites fall in the narrow range -2.9°/oo to +3.5°/oo, implying formation from magmatic emanations or from reducing fluids which leached sulphide minerals of magmatic derivation. $\delta^{34}S$ values for three barite samples are all close to +16°/oo, and it is not possible to draw firm conclusions from these data. Calcites from the same rock types as the pyrite have $\delta^{13}C$ values of -22.3°/oo to -4.2°/oo and $\delta^{18}O$ values between -4.0°/oo and -23.1°/oo, with an inverse $\delta^{13}C$/ $\delta^{18}O$ relationship. The more ^{13}C- depleted calcites probably incorporated CO_2 from organic C, and their $\delta^{18}O$ values are compatible with precipitation from magmatic or metamorphic fluids. Mixing of such fluids with meteoric waters is implied by the calcites with variably lower $\delta^{18}O$ values.

The above features indicate that the major processes leading to brecciation and associated metasomatism were hydraulic fracturing and hydrothermal activity resulting from ascent of granitic magmas to shallow crustal levels during late stages (Late Ordovician-?Silurian) of the Delamerian Orogeny. Tectonic and sedimentary processes appear to have played relatively minor roles in breccia formation, but deep weathering has modified the breccias.

EASTERN CREEK Pb-Ba PROSPECT, McARTHUR BASIN

by T.H. Donnelly

STAFF: T.H. Donnelly, M.D. Muir (CRAE) and R.W.T. Wilkins (CSIRO)

The aim of this investigation was to determine the genesis of the Eastern Creek Pb-Ba prospect and to extrapolate the results to examine other stratabound base-metal deposits of northern Australia.

A petrological, fluid inclusion, and stable isotope study was carried out on samples from the Kookaburra Creek Formation at Eastern Creek. As well, limited stable isotope studies in other areas of the McArthur Basin have been carried out on:

1. the Bulman mine,
2. the Looking Glass Formation (Battern Subgroup) at Beetle Springs, and
3. unmineralised units of the McArthur Group.

The results of these studies and implications for other stratabound base-metal deposits in the McArthur Basin region are discussed in the McArthur Basin section of this report. The study is at present being written up for publication.

MICROBIOLOGICALLY ENHANCED OIL RECOVERY

STAFF: B. Bubela, C.J. James, and V. Partridge.

SIMULATED RESERVOIR CONDITIONS

by B. Bubela

The investigation of the feasibility of microbiologically enhanced oil recovery is being supported by a grant from the National Energy Research Development and Demonstration Council. The early part of the program was concerned with the development of techniques and construction of instrumentation. The effect of microbiological activity on oil recovery from simulated oil reservoirs and on carbonate reservoir rocks has been reported previously.

Investigations of the relationship between pore size, permeability, oil saturation, and yield in recovery by microbiological techniques have shown that in water-wetted simulated systems the oil saturation diminishes with the decrease of the average pore size and the recovery becomes less efficient.

This effect may be contributed to by the increased role of capillary forces participating in the retention of the residual oil. The effect of an additional non-biological sweep of the simulated reservoir with water, at a variety of pressures and flow rates, increased the yield by less than 1%, thus indicating the efficiency of the biological technique.

It is assumed that most Australian reservoirs are water-wetted. Comparative tests were done to indicate the efficiency of microbiological techniques in oil and water-wetted systems. While in water-wetted reservoirs the increase in recovery of oil due to biological techniques was on average from 30-55%, the increase in the oil-wetted systems was usually about 10%.

The mode of dispersion of the oil through the reservoir differs from a more-or-less continuously oil-filled network of capillaries in the oil-wetted reservoir, to individual discrete pockets of oil in a predominantly water-filled network in the water-wetted system. A decrease in the water-oil interfacial tension and the improved mobility ratio of the oil-water system owing to biological activity appears to be more efficient in the former. The effect of the mode of dispersion on microbiologically enhanced recovery is now studied in more detail.

To facilitate the investigation of sweep velocities on the oil recovery a system consisting of porous cement blocks of predetermined permeability was developed. It was found that a sweep velocity of about 12 cm per day was the most efficient. Sweeps at higher velocities resulted in fingering, thus decreasing the oil recovery, while lower velocities did not improve the yields significantly.

Using cement blocks as simulated reservoir rocks permitted studies of the effects of the bacterial shapes and sizes on plugging of pore throats. Rod-shaped micro-organisms were more effective than spheroidal forms in plugging the pores. An increase of hydrostatic pressure by approximately 200 kPa was sufficient to break the plug produced by the spheroidal organisms, while an increase of pressure was ineffective with the rod-shaped organisms. More detailed investigation is in progress on the formation, shape, and stability of the microbiologically produced plugs and their dependency on bacterial concentration.

The effect of biological activity under simulated reservoir conditions on the oil composition was investigated. No significant differences were observed with oils of low asphaltene concentration. Samples of oil with asphaltene contents higher than 3% showed a considerable increase of viscosity, and an apparent increase in asphaletene content by up to 50% of the original value.

When asphaltenes from such oils were isolated their IR spectrum indicated the presence of a new component of a molecular weight of 3000 Daltons. This compound was not detected in the oil before biological treatment, nor when the oil was exposed to similar experimental conditions in the absence of the organisms. It is suggested that previously absent macro-molecular components are formed from some asphaltenes or other crude oil components and when standard techniques are used they are isolated simultaneously with natural asphaltenes.

A report indicating the enhancing effect of Mg and Cu on changes in oil composition due to microbiological activity was investigated but no significant changes were observed.

The construction of an instrument for continuous growth of organisms has been reported previously. When rod-shaped organisms were grown at a temperature of 60°C and a pressure of 20 000 kPa the organisms changed their shape to a spheroidal form. Where such an organism was suddenly exposed to a pressure drop from 20 000 kPa to atmospheric pressure, the cell burst and disintegrated. If the pressure change occurred over a period of several hours, the organism reverted to its original form. The variability of the morphology of the organisms with environmental changes is being further investigated, as their shape, as shown before, is significant in the plugging of the pores.

As it may be necessary to introduce a readily available source of carbon into the reservoir to achieve microbiologically enhanced oil recovery, a number of potential substrates were investigated for their suitability. The majority of them have been rejected so far, as some of their components form particles under reservoir conditions, thus affecting the reservoir rock permeability. Waste from the sugar cane industry, presently being tested, may be acceptable for our purpose.

INTERFACIAL TENSION AT THE OIL - AQUEOUS PHASE INTERFACE AND THE MOLECULAR PROPERTIES OF SURFACTANT SYSTEMS

by C.J. James

The aim of this study is to achieve, through the study of characterised surfactant systems, a greater insight into the relationship between the molecular properties of a surfactant system and the observed interfacial tension between Australian crude oils and the aqueous phase. In particular, the molecular properties required to generate ultra-low interfacial tensions (10^2 - 10^{-3} mN/m) which are, in turn, required to mobilise globular residual crude oil in the reservoir.

Scant information regarding the relationship between molecular properties at the oil-aqueous phase interface and the generation of ultra-low interfacial tensions could be found in the literature. Further, previous studies are rather restrictive in that the vast majority of them are concerned with ill-defined petroleum sulphonate systems. A broader understanding of the factors which lead to the generation of ultra-low interfacial tensions, derived from the study of well-defined surfactant systems, should lead to the more efficient selection of additional molecular systems for potential application to enhanced oil recovery.

Interfacial tensions are measured by the spinning-drop technique in a specially modified piece of equipment. Based upon the published literature, the present studies are the first-known extensive investigation concerning the interaction between Australian crude oils and aqueous surfactant solutions. Hence, an integral part of the present study is to ascertain the range of interfacial tensions that may be expected to be generated by Australian crude oils when they are contacted with an aqueous phase containing varying amounts of added components, e.g., surfactant(s) and electrolyte(s). As well as studying interfacial tensions, a further purpose of the experiments undertaken is to observe the behaviour of the oil and aqueous phases when the two are in contact e.g., whether a third phase is generated at the interface as an additional indicator of the extent of the interaction at the interface.

Figure B10 contains observations made during the present study of the sodium dodecylsulphate (SDS)/NaCl/n-pentanol/crude oil system. It is a plot of the interfacial tension (γ), as $\log_{10} \gamma$, when an Australian crude oil is contacted with a 2 wt% SDS solution containing varying concentrations of added component in the form of NaCl and pentanol.

When the concentration of NaCl is increased in the presence of 2 wt% SDS, γ is reduced, but not dramatically at this surfactant concentration, by the addition of NaCl (plot 1 of Fig. B10).

At the higher concentrations of NaCl studied (Fig. B10) SDS was observed to salt out of solution at room temperature ($\sim$20°C). That is, the presence of electrolyte had altered the hydrophilic-hydrophobic group interactions to such an extent that surfactant crystals were formed. SDS being a resonably pure sample of surfactant, with regard to chain length distribution, the addition of electrolyte has resulted in the formation of an extreme form of order within an initially liquid system, that of crystallinity. When the co-surfactant n-dodecanol was added to the last composition studied on plot 1 of

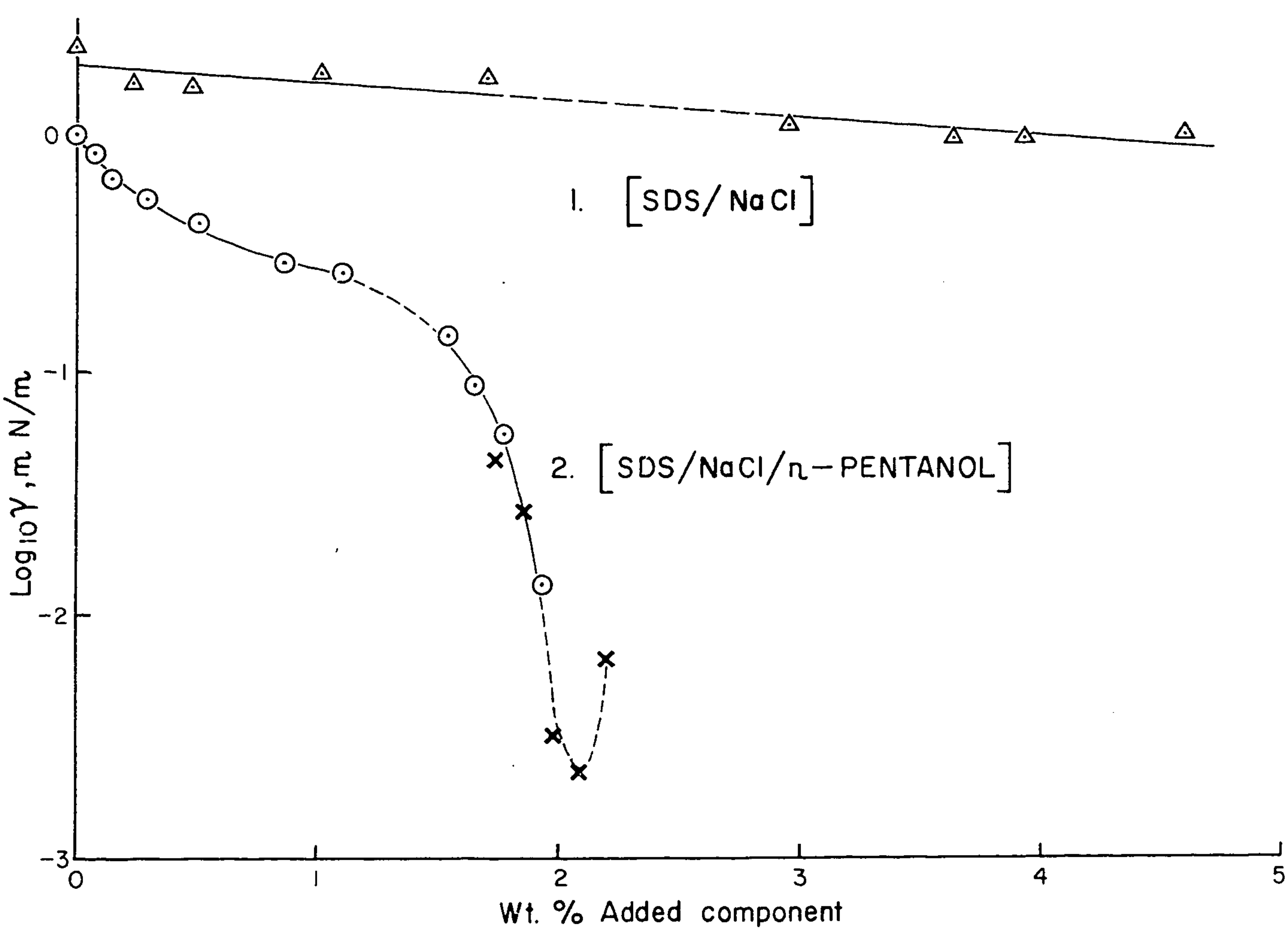

Fig B10 Plots of interfacial tension, γ, as $\log_{10}$ γ (mN/m) for an Australian crude oil against 2 wt.% SDS containing variable concentrations, as wt. %, of NaCl and pentanol at 30° C.

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Figure B10 (viz 2 wt% SDS and 4.5 wt% NaCl) a discontinuous phase, probably crystalline, was observed to form (cf. the salting out of SDS). In order to study the effect of the chain length distribution further, a co-surfactant, pentanol, of widely differing chain length to SDS, was also added to the last composition studied on plot 1 of Figure B10. The effect of γ between this last aqueous phase and an Australian crude oil by the addition of increasing amounts of pentanol can be seen from plot 2 of Figure B10. In a narrow range of pentanol concentrations ultra-low tensions are generated. It would appear therefore, for the compositions studied, that the combined effect of chain length disparity (between SDS and pentanol) and the two hydrophilic groups have resulted in the observed ultra-low interfacial tensions, $\sim 2\times10^{-3}$ mN/m. (Cf γ for crude oil and water $\sim$30 mN/m, γ for hair shampoo at working strength and crude oil $\sim$ 2 mN/m, the last value may be approximated by 2 wt% SDS in the absence of an added component on plot 1 of figure B10. It is interfacial tensions of the order of 10^{-2} - 10^{-3} mN/m that are required to mobilise globular residual crude oil in the fluid-rock ensemble in the oilfield.)

From the results presented in Figure B10 it was observed that ultra-low interfacial tensions were generated over a narrow range of compositions: pentanol in the presence of fixed concentrations of SDS and NaCl (i.e., in addition to water a three component aqueous phase). Therefore, it would appear that molecular orientations at the oil-aqueous phase interface that result in the observed low tensions are highly specific to the relative concentrations of electrolyte, surfactant, and co-surfactant. Research in progress and planned is aimed at understanding these observations in greater detail through the study of characterised surfactants such as SDS, e.g., by altering the chain length and/or the character of the co-surfactant.

CONFERENCES AND OTHER ACTIVITIES

The following conferences were attended by members of the Baas Becking Laboratory.

- Australian & New Zealand Society for Mass Spectrometry, Sydney, August: T.H. Donnelly, L.A. Plumb.

- Australian Sedimentologists Group Conference, Canberra, December: J. Bauld, R.V. Burne, J. Ferguson and L.A. Plumb.

- Proterozoic Symposium, Wisconsin U.S.A., May: J. Knutson, I.B. Lambert, M.R. Walter.

- Fifth Australian Geological Convention, Perth, August: J. Bauld, R.V. Burne, I.B. Lambert, M.R. Walter.

- Australian Society for Microbiologists, Canberra, May: J. Bauld, G.W. Skyring, P.A. Trudinger.

- 13th International Botanical Conference, Sydney, August: J. Bauld.

- Australian Society for Limnology, Narooma, May: J. Bauld.

- Salt Lakes Workshop, Canberra, September: J. Bauld, R.V. Burne, J. Ferguson, L.A. Plumb.

- XXVIII Symposium of the International Union of Pure and Applied Chemistry (Microbiologically Enhanced Oil Recovery), Vancouver, Canada, August: B. Bubela.

- Symposium of Biotechnological Processes (Microbiologically Enhanced Oil Recovery) Calgary, Canada: B. Bubela.

- Symposium on Government Involvement in Energy Production and Distribution - Australian Institute of Energy, Canberra, September: B. Bubela.

- International Symposium on Interaction of Particles in Colloidal Dispersions, Canberra, March: C.J. James.

- Institute of Radio and Electronic Engineers, Melbourne, August: I.A. Johns.

- Landsat 81, Canberra, September: I.A. Johns.

- Symposium on Sulfide Mineralisation in Sediments, Canberra, March: J. Bauld, B. Bubela, R.V. Burne, T.H. Donnelly, J. Ferguson, J. Knutson, I.B. Lambert, L.A. Plumb, G.W. Skyring, P.A. Trudinger, M.R. Walter.

- Conference on The Geochemistry of Organic Matter in Ore Deposits, Virginia USA, November: P.A. Trudinger.

- Carbonate Workshop, Canberra, August: R.V. Burne, T.H. Donnelly, J. Ferguson.

IRIAN JAYA GEOLOGICAL MAPPING PROJECT

Project Manager: D.B. Dow

IRIAN JAYA GEOLOGICAL MAPPING PROJECT

by

D.B. Dow & B.C. Barlow

INTRODUCTION

BMR is the managing agent for the Irian Jaya Geological Mapping Project, which is an Australian Colombo Plan aid project in which the main aim is to assist Indonesia in developing modern geological and geophysical surveying techniques suitable for the mountainous jungle-covered terrain that constitutes a large proportion of Indonesia's land area. Thus, it is predominantly a training project in which training in logistics and organisation of field operations is an important as training in the technical aspects.

The geological mapping of Irian Jaya (the western half of the island of New Guinea) was chosen as a suitable project, partly because it provides training in a wide range of terrains and poses enormous difficulties of access, but also because its geology and mineral potential is so poorly known. Consequently a second, and equally important, objective of the project is to carry out a regional gravity survey of Irian Jaya. A systematic geochemical stream-sediment and panning survey is being carried out currently with the geological mapping, so that a proper mineral assessment can be made.

The work is being done jointly with the Geological Research and Development Centre (GRDC), a Directorate of the Indonesian Department of Mining and Energy. The main contribution from Australia is of technical personnel, equipment, and the charter of helicopters which are the principal means of transport to gain access to the interior.

The project is based at GRDC headquarters in Bandung, the capital of West Java which is located 180 km by road from Jakarta. All project personnel live in Bandung, which is a large, predominantly government city and provides very pleasant living conditions. Fieldwork is carried out for six months each year, and the rest of the time is spent compiling results and writing reports.

1981 was originally scheduled to involve no fieldwork so that the great amount of data accumulated during the three field seasons from 1978 to 1980 could be processed (Fig. J1). However, following a request from GRDC fieldwork was scheduled in 1981 to map the geology of Japen Island. In addition, project geologists carried out regional geological mapping and a gravity survey while accompanying a fossil collecting expedition mounted by GRDC to Misool Island 150 km to the north. The charter of the ship used by the expedition was extended so that a gravity survey could be done of Misool Island. In addition, a geological team from GRDC, including members of the Irian Jaya Project, used the logistics provided to revise the geological map of this island.

During July, project personnel accompanied G. Small of BMR to assist him in setting up first-order magnetic stations in Irian Jaya. Advantage was taken of the logistics provided by GRDC to establish a gravity control network.

The Project Staff are listed in Table J1.

TABLE J1
IRIAN JAYA PROJECT STAFF

	AUSTRALIAN		INDONESIAN	
	NAME	TITLE	NAME	TITLE
GEOLOGICAL	D.B. Dow	Project Manager	R. Sukamto	Project Comanager
	D.S. Trail	Supervising Geologist	Nana Ratman	Project Leader
	P.E. Pieters	Group Leader	Sumitra Atmawinata	Geologist
	R.J. Ryburn	Group Leader	Udi Hartono	Geologist
	C.J. Pigram	Group Leader	Aang Achdan	Asst. Geologist
	G.A. Robinson	Geologist Instructor	Sahat L. Tobing	Asst. Geologist
			Bhakti H. Harahap	Asst. Geologist
			Chairul Amri	Asst. Geologist
			A. Sufni Hakim	Asst. Geologist
			Hermes Panggabean	Asst. Geologist
			Endang Suryana	Draughtsman
			Philips Waromi	Draughtsman
			Temon	Draughtsman
			Titersole	Draughtsman
GEOPHYSICAL	B.C. Barlow	Project Geophysicist	G.S. Akil	Project Leader
		(Geophysical	Sutisna Sukardi	Senior Geophysicist
	Vacant	(Technical Officer	Mohamad Untung	Senior Geophysicist
			Nazhar B.	Geophysicist
			Jufri Nasution	Junior Geophysicist
			Juniar Parademahan	Junior Geophysicist
			Imam Sobari	Junior Geophysicist
			Marzuki Sani	Junior Geophysicist
			W.H. Simamora	Junior Geophysicist
			Sardjono (?)	Physicist
			Bundan Mubroto	Physicist
			Marlan	Physicist
			Nasir Syarif	Physicist
			Neni Sri Utami	Programmer
			Siti Zahar Besari	Programmer

TABLE J1 (contd)

	AUSTRALIAN		INDONESIAN	
	NAME	TITLE	NAME	TITLE
GEOPHYSICAL (cont'd)			Imam Margono	Senior Draughtsman
			S. Oyon	Draughtsman
			Warsono A.P.	Senior Tech.Officer
			Udjun D.	Technical Officer
ADMINISTRATIVE	G.A. Dunn	Administrative Officer	A. Sasmita	Accounts Clerk
			I. Lukman	(Secretary/ (Receptionist
			T. Madjid	Secretary/Typist
			Y. Ibrahim	Typist/Clerk
			Harli Sumadirdja	(Counterpart- (Liaison
			Dian Syaiful	(Maintenance (Officer
			Maxie Johannes	Head Driver
			Nana S.	Driver
			Yayat	Driver
			Iskandar	Driver
			Wahyu	Driver
			Leo Sambas	Driver

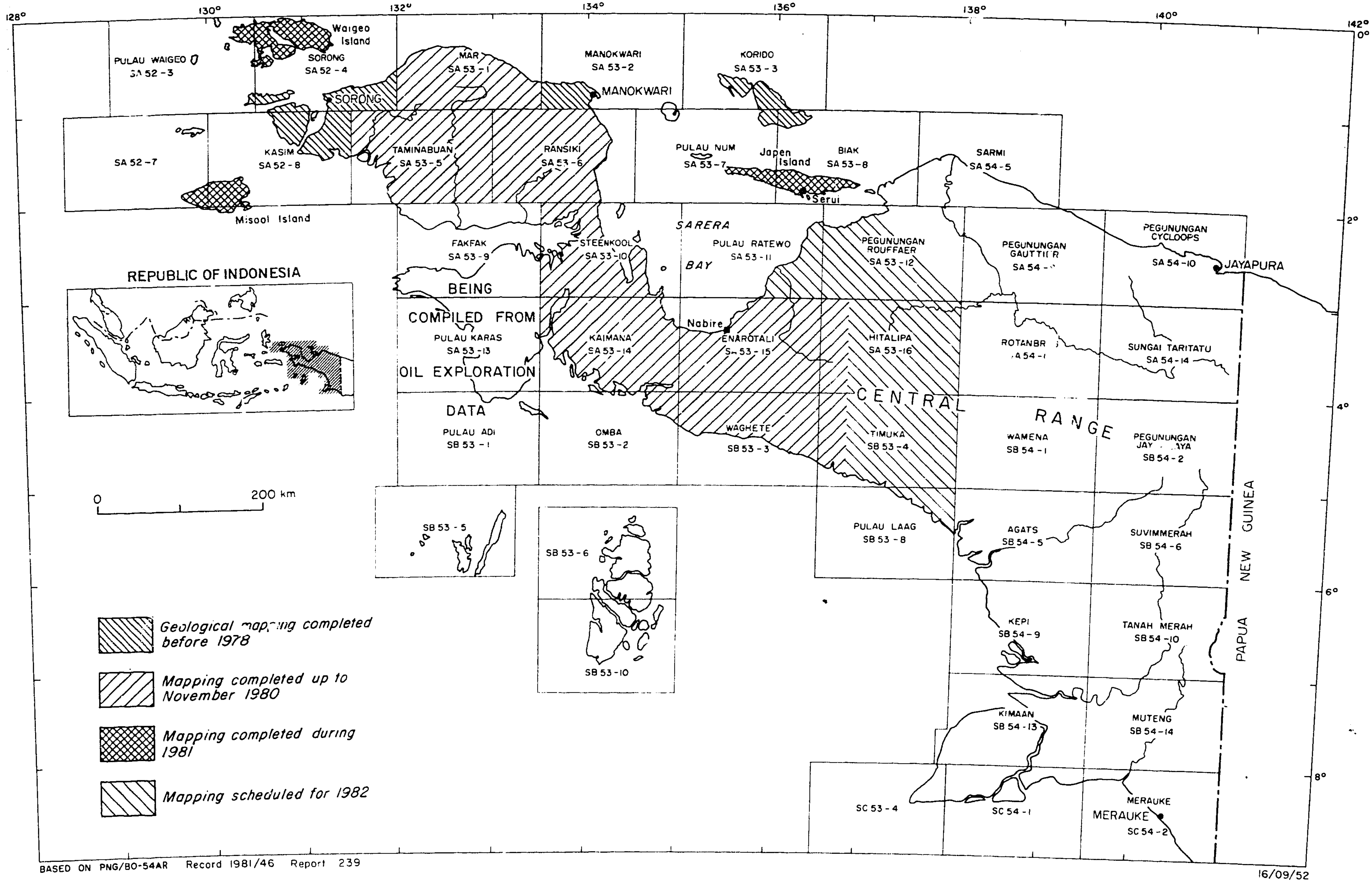


Fig. J1 Geological and geophysical mapping, Irian Jaya

GEOLOGICAL PROGRESS

FIELD MAPPING

The geology of Japen Island (Fig. J1), which is a narrow east-west-trending island that blocks most of the mouth of Sarera Bay (Geelvink Bay), was started in early September and was completed by the end of October. It is a rugged entirely jungle-covered island, 175 km long by a maximum of 30 km wide, which rises to over 1500 m high near the centre. Thus it is ideally suited to mapping from the coast using the project's de Havilland River Trucks for access.

The first base camp was set up near Windisi Village on the north coast about 50 km from the western tip, and the second at Serui on the south coast, and the geology was mapped along the coast directly from the river trucks, and inland by traversing all the streams draining to the northern slope, also using the river trucks for transport to the river mouths. For areas distant from the base camps, fly camps were set up using a local outrigger canoe, hired by GRDC and powered by the project's outboard motors, to carry the necessary equipment.

The mapping was entirely the responsibility of our Indonesian counterparts, and was completed efficiently and in considerable detail. Dow, Trail, and Pieters were the Australian members that took part in the mapping. Stream-sediment and panned samples were taken meticulously, but probably to no avail as the rocks are conspicuously void of any signs of mineralisation.

The months of September and October were chosen for the survey because they are the doldrums, and calm weather is essential for making landings, especially on the north coast. Nevertheless, broad swells rolling in from the Pacific Ocean made landing on the eastern end of the north coast a somewhat hazardous undertaking, mainly because the river trucks are not designed for such work and the low transom is disconcertingly prone to dip under in short steep rollers. Such occasions are especially disconcerting to those of our counterparts who cannot swim. However, there is little danger because there is no undertow, the river trucks have built-in buoyancy, and once away from the narrow zone of breaking near the beach the long swells pose no problems. Even in the event of a swamping, the river truck can be bailed out either onshore or else away from the breakers.

DATA STORAGE, COMPILATION, AND REPORT WRITING

The Preliminary editions of three 1:250 000 geological maps (Mar, Taminabuan, and Enarotali) were published during the year, and the remaining maps (Ransiki, Steenkool, Kaimana, Waghete, and Omba) were on schedule to be published by March 1982.

Comprehensive data records are to be published for each of the Sheet areas and by the end of the year the first draft of the Taminabuan data record had been completed.

A major task was completed during the year with the storage in the project Hewlett Packard Mini 1000 computer of all the geological data collected to date. Another major achievement was the programming of the computer for editing on disc and for retrieval of the data.

GEOPHYSICAL PROGRESS

FIELD MAPPING

Mapping completed to October 1981 is shown in Figure J1, and is virtually up to schedule in spite of delays caused by helicopter unserviceability.

Additional helicopter coverage was obtained from camps at Nabire, Modio, and Enarotali during November/December 1980. Boats were used to obtain a coverage over Misool and Waigeo during April/June 1981. Readings were obtained around the coastline of each main island, and hundreds of readings were obtained on numerous small islands to give coverage out to distance of tens of kilometres.

First-order magnetic stations were satisfactorily established at Jayapura, Biak, and Sorong (Fig. J4). A magnetic storm and strong local interference downgraded the accuracy of the magnetic station establishment at Timika and it will probably be rated as second-order.

The accuracy of gravity ties made between these stations of the gravity control network is generally satisfactory although of lower quality than the ties made in Australia. A gravity tie between the most easterly Indonesian base station, Jayapura, and the absolute station at Port Moresby, PNG, verified that the eastern part of the Indonesian network is on absolute datum to within a few hundredths of a milligal.

DATA STORAGE, COMPILATION, AND REPORT WRITING

Data from the 1978 and 1979 field seasons were recomputed on the Cyber 76 computer in Canberra during April and May to correct a large number of errors. Computer-drawn maps of Kepala Burung were prepared at a scale of 1:250 000. The 1980 helicopter survey data have not yet been processed by computer; these data will be computed on the HP system 1000 at Bandung. Several major breakdowns of the HP system 1000 have delayed introduction of the gravity programs.

Results from the 1980 and 1981 field season have been hand-computed using desk-top calculators.

GEOLOGICAL RESULTS

The mapping of the Enarotali and Waghete Sheet areas (Fig. J1) has revealed a remarkable thrust, the Weyland Overthrust, which is a slab 100 km wide of rocks of oceanic affinities that has been thrust 35 km southwards over the northern margin of the Australian continent (Fig. J2).

WEYLAND OVERTHRUST

Upper Palaeozoic, Mesozoic, and Tertiary platform sediments overlying Australian continental crust extend northwards under the Central Range (Fig. J1). To the north, metamorphosed trough-type sediments of Mesozoic and Tertiary age form an east-west-trending belt along the northern margin of the continental block. The northern margin of these metamorphics is formed by a wide belt of ultramafic rocks and blueschists metamorphics.

The Weyland Overthrust is a segment of the metamorphics and ultramafic rocks intruded over the whole of its width by a middle Miocene dioritic batholith, which has been thrust southwards over the platform sediments. The displacement of 35 km is shown unequivocally by the disruption of the southern margin of the metamorphics and the belt of ultramafic rocks.

The thrusting postdates the emplacement of the diorite batholith and can therefore be no older than late Miocene and is probably much younger. The fact that the toe of the thrust forms the arcuate and isolated Weyland Range nearly 400 m high indicates a much younger age for the thrusting. In fact, it is apparent from the seismicity of the region and the marked physiographic expression of the faults, of which some displace recent alluvial fans, that the thrusting has continued to the present day.

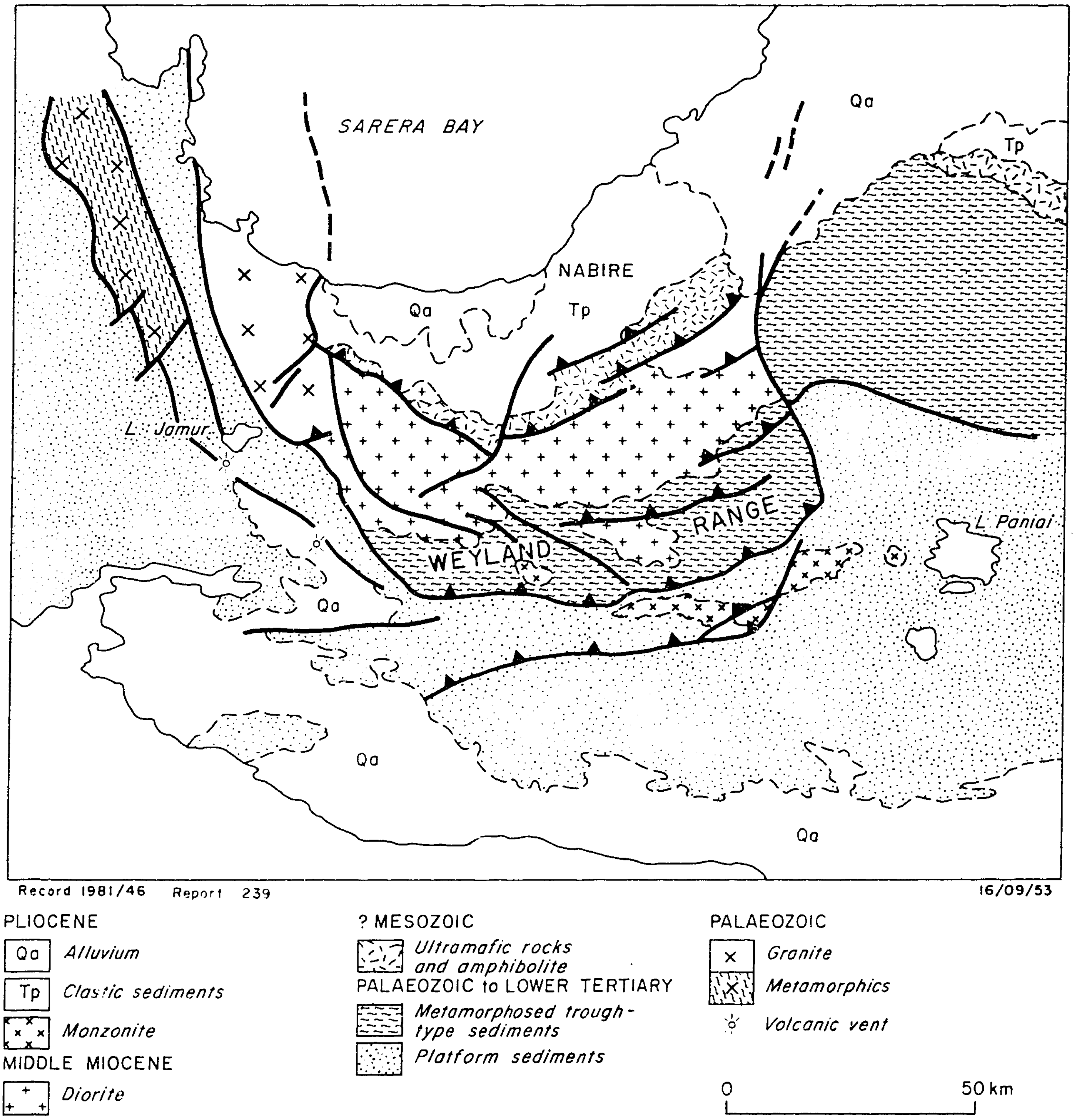


Fig J2 Geology of Nabire Region, Irian Jaya

RECENT VOLCANISM

Further evidence of the recent nature of the earthmovements was given by the discovery during the mapping of a recent andesitic cone with a well-developed crater south of Lake Jamur. This is the first record of a recent volcano in Irian Jaya.

The cone is about 3 km across and is located at the junction of 2 major faults. Its formation played a major part in the damming of the lake. Though volcanic rocks were mapped during two traverses that touched its flanks the presence of the cone was unsuspected because the airphotographs available for the mapping were mainly obscured by cloud.

Recently flown airphotographs of good quality revealed the morphology of the volcano and also the presence of another probable volcanic dome on the southeasterly extension of one of the faults.

PROBABLE SILURO-DEVONIAN PLATFORM SEDIMENTS

In the 'bird's head' the oldest platform sediments belong to the Aifam Group which is of Late Carboniferous age at its base, and rests unconformably on the probable Palaeozoic Kemum Metamorphics. A notable discovery during the last half of the 1980 field season mapping was the presence of thick platform sediments conformably underlying the Aifam Group.

The sediments consist of a thick (1000 m plus) dolomite underlain by an unknown thickness of black shale which contains, near the base of the dolomite, a conodont fauna of Siluro-Devonian affinities.

SOURCE OF OIL PRODUCED IN THE 'BIRD'S HEAD'

The origin of oil produced from buried Miocene limestone reefs in the 'bird's head' region is unknown, but maturation studies done by the oil companies on the oldest sediments (Mesozoic) penetrated to date by exploration wells show that they are too immature to have been the source of the oil.

The mapping done by the project has shown the presence of likely source beds lower in the platform succession. Thick beds of black organic shale occur in the Aifam Group and also below the underlying dolomite, and though no maturation studies have been done on these rocks, it is thought that the greater depth of burial they have undergone may have been sufficient to produce oil.

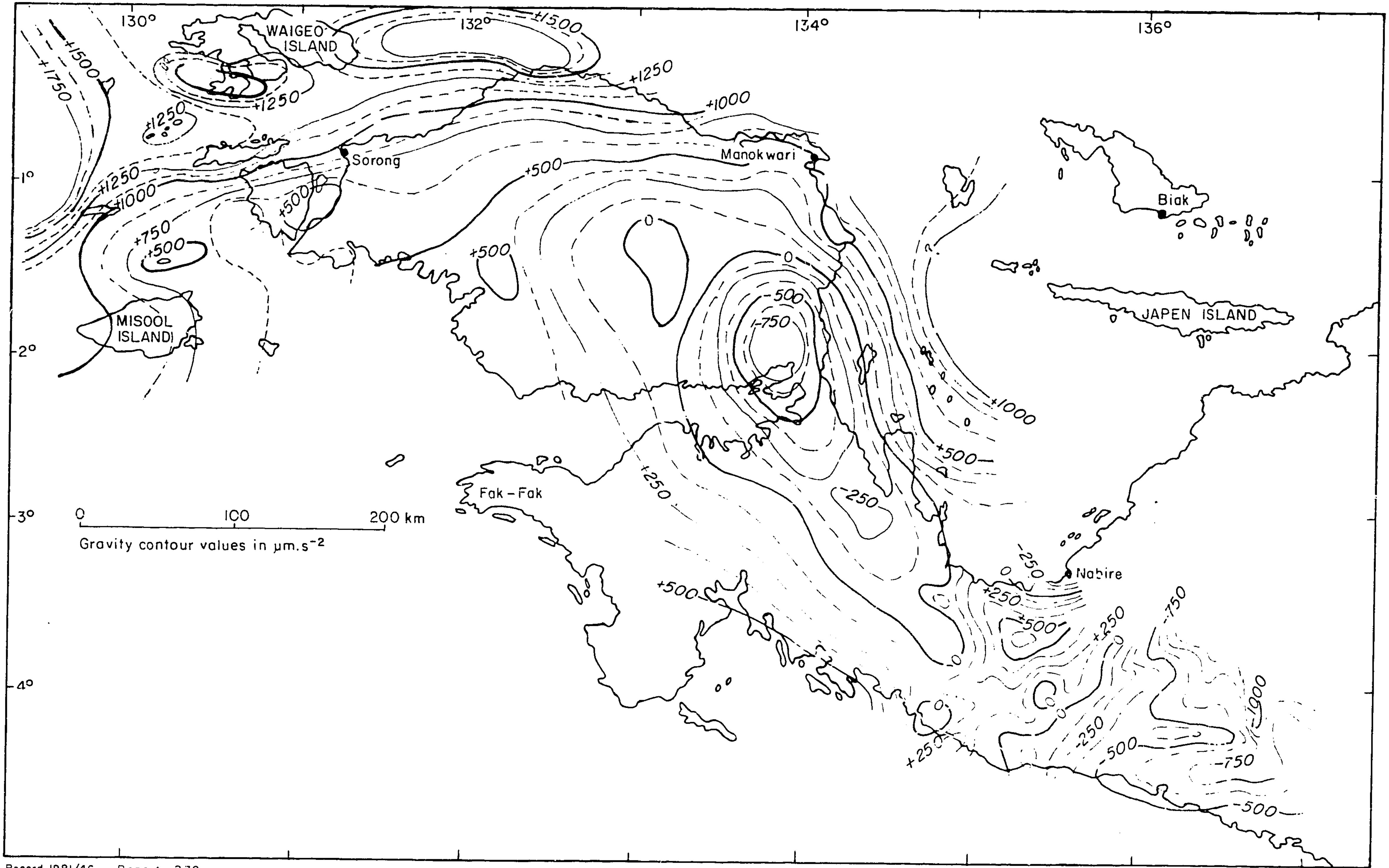
Source-rock studies have not been done to date by the project, but in the absence of regional studies by the oil companies, suitable outcrop samples will be tested in future.

GEOPHYSICAL RESULTS

Preliminary Bouguer anomaly contours for the areas surveyed in 1978, 1979, 1980 and 1981 are shown in Figure J3; the 1981 gravity control network is shown in Figure J4.

The gravity picture in the central part of this map has been described in the previous Annual Summary (BMR Report 230). Data obtained this year in the area south of Nabire show an east-west gravity low with Bouguer anomaly values as low as -800 $\mu m.S^{-2}$ in the eastern part of the Waghete Sheet area, indicating a thick sedimentary section under the southern coastal plain. Gravity values in the 'bird's neck' are surprisingly positive and may be caused by a raft (or wedge) of oceanic crust or by higher-density material contained in a large batholith, of which various parts are seen in outcrop. Intense local gravity gradients are suggested by the helicopter data; some of these are confirmed by earlier, more detailed Shell Company traverses along rivers.

The data obtained on islands north of Misool show a relative gravity low northeast of Misool in an area where a thick section of sediments is known to exist in an isolated borehole. Northwest of Misool an extremely intense gravity gradient shows that the Sorong Fault Zone continues west-southwest up to the western edge of the map area. Earlier gravity maps show the zone swinging to the northwest off the western edge of Waigeo. The data over Waigeo and its surrounding islands show a complex series of mainly east-west relative gravity lows with values of 750 $\mu m.S^{-2}$ lower than the normal value of about +1750 $\mu m.S^{-2}$ along the northern margin of the Sorong Fault Zone. These lows are probably caused by thick local sections of sediment.



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16/09/54

Fig. J3 Preliminary Bouguer anomaly map, Irian Jaya Geophysical Survey 1978, 1979, 1980 and 1981

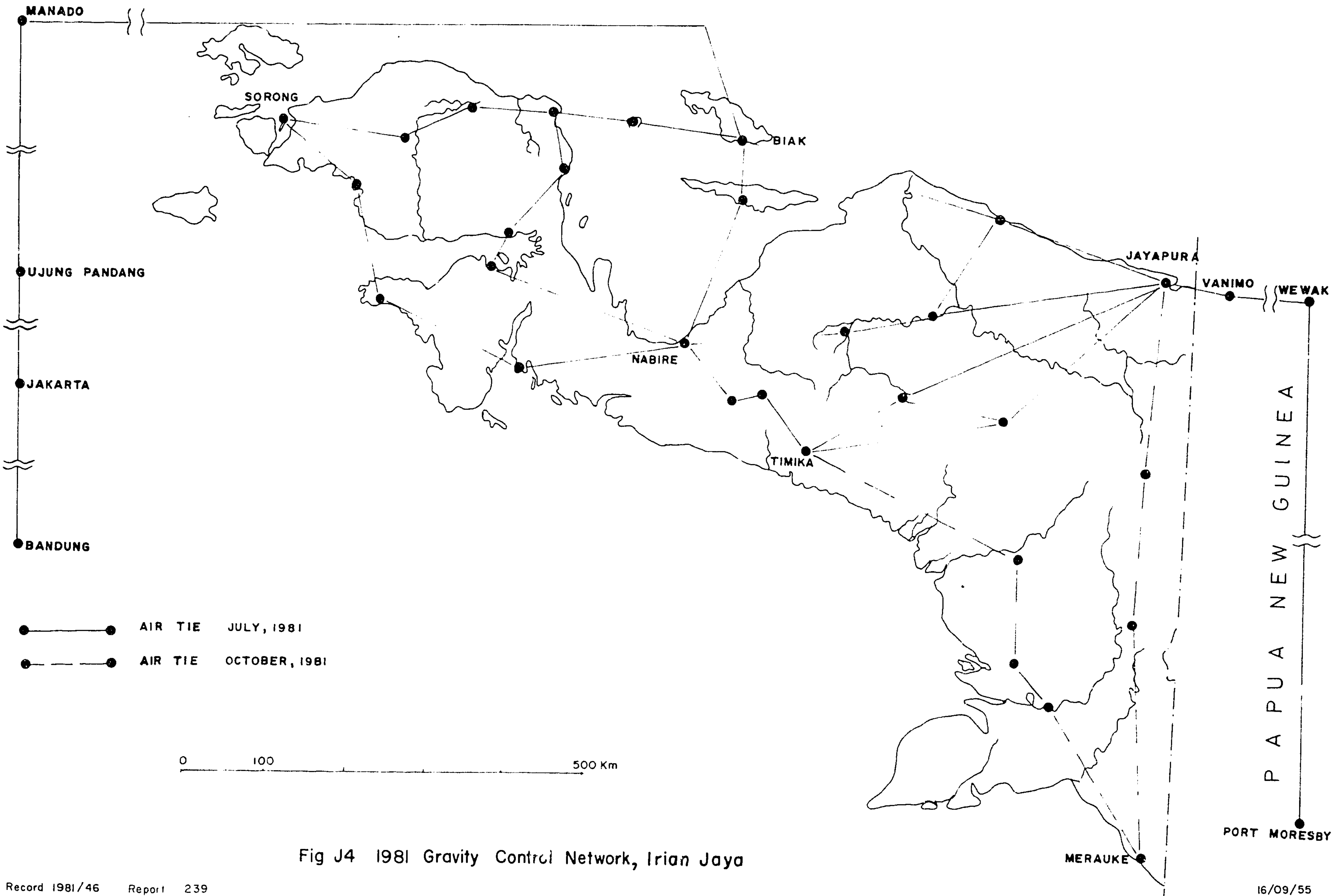

Fig J4 1981 Gravity Control Network, Irian Jaya

PUBLICATIONS

Officers of BMR report the results of their studies in a variety of BMR publications - both texts and maps - and in publications by other organisations; some results are recorded in BMR Open File Records and in Professional Opinions, which, though available for inspection (and generally for copying), are not regarded as publications. Listed in this section are all available reports and papers prepared in the Geological Branch during the period under review and those prepared in earlier years and issued during the period. The period of concern is from November 1980 to October 1981. The categories used are set out below; against each category the number of reports, papers or maps issued is given. The figures in brackets are for the corresponding period last year, as listed in Record 1980/61 and microfiche Report 230.

Bulletins	:	Published 7(8) or in press 4 (5)
	:	With editors 3 (9)
Reports	:	Published 8 (2) or in press 3 (5)
	:	With editors 4 (8)
Mineral Resources Reports	:	In preparation 1 (0)
Contributions to BMR Yearbooks	:	Published 7 (6)
	:	In preparation 9 (6)
Contributions to AMI Reviews	:	Published 2 (0) or in press 1 (1)
	:	In preparation 1 (0)
BMR Journal of Australian	:	Published 37 (24) or in press 8 (10)
Geology and Geophysics	:	With editor 7 (3)
Other BMR Publications	:	Published 0 (2)
Outside Publications	:	Published 118 (127) or in press 82 (86)
	:	Submitted and accepted 28 (15), or in preparation 27 (13) (for BMR authors 'in preparation' means that the paper is with editors).
Records	:	Issued 34 (79)
	:	With editors 18 (10)
	:	In preparation (being edited within the Geological Branch) 6 (8)
Professional Opinions	:	Issued 23 (22)
Other unpublished works	:	0 (5)

Maps. Maps are geological maps unless otherwise stated. For maps that have explanatory notes, the stage of progress indicated is that of the less advanced of the two.

1:250 000-scale maps	
Colour edition, with explanatory notes	
	: Published 1 (4) or in press 6 (2)
	: With editors 12 (13)
Preliminary edition (no notes)	: Published 9 (4) or in press 2 (0)
1:100 000-scale maps	
Colour edition	: Published 3 (8) or in press 2 (1)
	: With editors 13 (8)
Geochemical maps	: Published 2 (0) or in press 0 (2)
Preliminary edition	: Published 10 (13) or in press 3 (3)
	: In preparation 4 (6)
Special Maps	: Published 7 (6) or in press 2 (0)
	: With editors 5 (12)
	: In preparation 2 (0)
	: Preliminary edition published 0 (2)
BMR Earth Science Atlas of Australia (Topic Sheets)	: Published 1 (6) or in press 2 (0)
	: With editors 2 (2)
	: In preparation 1 (2)

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 Laboratory, and is not, or was not, a BMR officer

[4]is, or was, a member of a university or other tertiary educational institution

[5]is not, or was not, a BMR officer and does not fall into categories 1 to 4.

Year of publication or issue is not necessarily shown unless it is known to be other than 1981.

BULLETINS

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*175	[1]OPIK, A.A.	Dolichometapid trilobites of Queensland, Northern Territory and New South Wales.
182	[1]COOK, P.J. [2]MAYO, W.	Geochemistry of a tropical estuary (Broad Sound, Queensland).
*187	SHERGOLD, J.H.	Late Cambrian (Idamean) trilobites: Burke River area, western Queensland.
198	WELLS, A.T.	Evaporites in Australia.
205	[1]KENNEWELL, P.J. HULEATT, M.B.	Geology of the Wiso Basin, Northern Territory.
206	JACKSON, M.J. [2]VAN DE GRAAFF, W.J.E.	Geology of the Officer Basin, Western Australia.
207	MARSHALL, J.F.	Continental shelf sediments: southern Queensland and northern New South Wales.
209	PALAEONTOLOGICAL PAPERS	
	DICKINS, J.M.	A Permian invertebrate fauna from the Warwick area, Queensland, and the effect of water temperature on correlation.

SKWARKO, S.K.	Mesozoic molluscs from Papua New Guinea and northern Australia (6 papers, as below).
	Some Neocomian bivalves from northern Queensland, north-eastern Australia.
	A new late Mesozoic trigoniid and other bivalves from near Olsobip, western Papua New Guinea.
	First report of Megatrigoniinae/ bivalvia Cretaceous from Papua New Guinea.
	Nototrigonia cinctuta (bivalvia: mainly Early Cretaceous) in northern Queensland and Papua New Guinea.
	On the Trigoniinae, Nototrigoniinae and Austrotrigoniinae.
	Australian Cretaceous ammonites in the island of New Guinea.
YOUNG, G.C. [1]GORTER, J.D.	A new fish fauna of Middle Devonian age from the Taemas/ Wee Jasper region of New South Wales.
BELFORD, D.J.	Co-occurrence of middle Miocene larger and planktic smaller Foraminifera, New Ireland, Papua New Guinea.

*210	FORMAN, D.J. [1]WALES, D.W. (Compilers) Contributors: BURNE, R.V. FORMAN, D.J. [1]GORTER, J.D. PASSMORE, V.L. [1]RASIDI, J.S. [1]TUCKER, D.H. [1]WALES, D.W.	Geological evolution of the Canning Basin, Western Australia.
211	KENNARD, J.	The Arrinthrunga Formation: Upper Cambrian epeiric carbonates in the Georgina Basin, central Australia.
*213	STAGG, H.M.J. EXON, N.F.	The geology of the Scott Plateau and Rowley Terrace, off northwestern Australia.
	Appendix by: BELFORD, D.J.	Late Cretaceous planktic foraminifera in Valdivia core KL1 from the Scott Plateau, off northwestern Australia.

WITH EDITORS

212	WELLS, A.T. MOSS, F.J.	The Ngalia Basin, Northern Territory - stratigraphy and structure.
	CHAPRONIERE, G.C.H.	Mid-Tertiary larger Foraminiferida from Australia and New Zealand.
	TOWNER, R.R. GIBSON, D.L.	Geology of the onshore Canning Basin, Western Australia.

REPORTS

Reports are published in microform. The MF numbers given below are the serial numbers for the microfiche.

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*181 MF153	RADKE, B.M.	Lithostratigraphy of the Ninmaroo Formation (Upper Cambrian - Lower Ordovician), Canning Basin.
214 MF92	WALTER, M.R.	Adelaidean and Early Cambrian stratigraphy of the southwestern Georgina Basin: correlation chart and explanatory notes.
219 MF114	[1]NORVIK, M.	Permian and Late Carboniferous palynostratigraphy of the Galilee Basin, Queensland.
*221 MF154	WARREN, R.G.	Tectonic setting of the easternmost Arunta Block.
225 MF150	SWEET, I.P.	Definitions of new stratigraphic units in the Seigal and Hedleys Creek 1:100 000 Sheet areas, Northern Territory and Queensland.
226 MF151	SWEET, I.P. MOCK, C.M. MITCHELL, J.E.	Chemical analyses of igneous rocks from the Seigal and Hedleys Creek 1:100 000 Sheet area, Northern Territory and Queensland.

227 MF147	[4]GUST, D.A. JOHNSON, R.W. [4]CHAPPELL, B.W.	Petrological data catalogue for Boisa Island, an andesitic volcano in Papua New Guinea: whole-rock, mineral, and modal analyses and modelling data.
228 MF157	[1]WILLCOX, J.B. SYMONDS, P.A. [5]BENNETT, D. [5]HINZ, K.	Lord Howe Rise area, offshore Australia.
229	[5]ARCULUS, A. JOHNSON, R.W.	1937 Rabaul eruptions, Papua New Guinea: translations of contemporary accounts by German missionaries.
230 MF159		Geological Branch Summary of Activities 1980.
*233 MF164	BLAKE, D.H. [1,2]BULTITUDE, R.J. [2]DONCHAK, P.J.T.	Definitions of newly named and revised Precambrian stratigraphic and intrusive rock units in the Duchess and Urandangi 1:250 000 Sheet areas, Mount Isa Inlier, northwestern Queensland.

<u>WITH EDITORS</u>

234	HABERMEHL, M.A.	Investigations of the geology and hydrology of the Great Artesian Basin, 1878-1980.
235	HABERMEHL, M.A.	Springs in the Great Artesian Basin, Australia - their origin and nature.

[1]ELLIS, D.J. WYBORN, L.A.I.	Petrology of the Precambrian basic igneous rocks of the Mount Isa Region.
STRUSZ, D.L.	Size and distribution statistics, Wenlock brachiopods from Canberra, Australia.

<u>CONTRIBUTIONS TO BMR 80</u> (Published)

FORMAN, D.J. GIBSON, D. HULEATT, M. PERKIN, D.J.	Australia's resources of energy minerals and their assessment.
JACOBSON, G.	An unusual pollution problem in Canberra.
JONES, H.A.	Manganese nodules on the ocean floor.
OZIMIC, S.	Storage of gas for New South Wales in natural rock reservoirs.
SIMPSON, C.	Georgina Basin Project.
STEWART, A.J.	Yilgarn geological mapping.

<u>CONTRIBUTIONS TO BMR 81</u> (In preparation)

BARLOW, A. DOWNIE, D. OWEN, M.	Computers in BMR.
BURNE, R.V.	Spencer Gulf - testing ground for a model of ore formation.

JACOBSON, G.	Groundwater in small coral islands - recent BMR aid investigations in the Pacific.
JAQUES, A.L.	Meteorites as space probes.
KELLETT, J.	Hydrology in urban development.
OZIMIC, S.	Toolebuc Formation oil shale study.
SHERGOLD, J.	Phosphorite research.
WYBORN, D.	Geological studies in north Victoria Land, Antarctica.
YEATES, A.	Tasmanian tin and tungsten granites - their radiometric characteristics.

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GIBSON, D.L.	Oil shale in Australia - its occurrence and resources. 33-3.
JONES, H.A.	Deep sea manganese nodules in the Australian region. 33-1.

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IN PREPARATION

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5(4)	[3]BUBELA, B.	Some aspects of interstitial water movements in simulated sedimentary systems. 257-263.
5(4)	JACOBSON, G. HILL, P.J.	Hydrogeology of a raised coral atoll - Niue Island, South Pacific Ocea. 271-278.
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6(1)	[5]TURNER, S. JONES, P.J. [1,2]DRAPER, J.J.	Early Devonian thelodonts (Agnatha) from the Toko Syncline, western Queensland, and a review of other Australian discoveries. 51-69.
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6(2)	CHAPRONIERE, G.C.H.	Australasian mid-Tertiary larger foraminiferal faunas and their bearing on the East Indian Letter Classification. 145-151.
6(2)	DAVIES, P.J. WEST, B.G.	Suspended sediment transport and water movement at One Tree Reef, southern Great Barrier Reef. 187-195.
6(2)	EXON, N.F. BURGER, D.	Sedimentary cycles in the Surat Basin and global changes of sea level. 153-159.
6(2)	WEST, B.G. DAVIES, P.J.	The determination of suspended sediment loads in the southern Great Barrier Reef: field techniques. 181-185.
6(3)	BLACK, L.P.	Age of the Warramunga Group, Tennant Creek Block, NT 253-257.

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MOSS, F.J. [1]PINCHIN, J. [1]SENIOR, B.R.	Regional geology, geophysics, and petroleum potential of the central Eromanga Basin area.
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WYBORN, L.A.I.	Aspects of the geochemistry and economic potential of the felsic igneous rocks of the Mt Isa Region.

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*6(4)	[3]DONNELLY, T.H.	Precambrian sulphur isotopes: implications for the global sulphur cycle.

*6(4)	[3]FERGUSON, JAMES BURNE, R.V.	Interactions between saline redbed groundwaters and peritidal carbonate sediments: significance for stratiform Cu ore genesis.
*6(4)	JACKSON, M.J.	Syngenetic mineralisation in the Wollogorang Formation, McArthur Basin, NT.
*6(4)	KNUTSON, J.	Geochemical and mineralogical constraints on the genesis of Cu mineralisation in the Mount Gunson region, South Australia.
*6(4)	[3]LAMBERT, I.B.	Metal sources and fixation in some stratiform deposits.
*6(4)	RADKE, B.M.	Saddle dolomite gangue: an indicator of epigenetic mineralisation in sediments.
*6(4)	[3]TRUDINGER, P.A.	Origins of sulphide in sediments.
*6(4)	[3]BAULD, J.	Geobiological role of cyanobacterial mats in sedimentary environments: production and preservation of organic matter.

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	BLAKE, D.H. [1,2]BULTITUDE, R.J. [2]DONCHAK, P.J.T.	Proterozoic intrusive breccia bodies near Duchess, north-western Queensland.

BROWN, C.M. JACKSON, K. LOCKWOOD, K.L. PASSMORE, V.L.	Source rock potential and hydrocarbon prospectivity of the Darling Basin.
BURNE, R.V.	Relative fall of Holocene sea level and coastal progradation, northeastern Spencer Gulf, South Australia.
NICOLL, R.S.	A middle Ordovician conodont fauna from the Pittman Formation, Canberra, A.C.T.
SHAFIK, SAMIR	Biostratigraphic correlation by means of Eocene calcareous nannofossils from the Otway Basin, southeastern Australia.
STRUSZ, D.L.	On <u>Australina</u> Clarke - and its junior synonyms <u>Lissatrypa</u>, <u>Lissatrypoidea</u>, and <u>Tyrothyris</u> (Silurian-Devonian Brachiopoda).
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*[4]ARCULUS, R.J. JOHNSON, R.W.	Island-arc magma sources: a geochemical assessment of the roles of slab-derived components and crustal contamination.	Geochemical Journal.

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Parts of 5071, 5072, 5171, 5172	Rum Jungle, (Special)	CRICK, I.H.
*5171, part 5170	Batchelor-Haves Creek (Special)	CRICK, I.H.
*5270	Pine Creek	STUART-SMITH, P.G. NEEDHAM, R.S. WALLACE, D.A. [2]ROARTY, M.J. [2]BAGAS, L.
5271	McKinlay River	WALLACE, D.A. NEEDHAM, R.S. STUART-SMITH, P.G. [2]ROARTY, M.J.
5272, 5273	Mary River/Point Stuart (Special)	STUART-SMITH, P.G. WALLACE, D.A. [2]ROARTY, M.J.
5550	MacDonnell Ranges	OFFE, L.A. & OTHERS
5851	Riddoch	SHAW, R.D. & OTHERS
Part 6360 & 6460	Carrara Range Region (Special)	SWEET, I.P. MOND, A. [2]HUTTON, L.J.
Part 6560 & 6561	Constance Range Region (Special)	MOND, A. SWEET, I.P. [2]HUTTON, L.J.

6759, part 6760	Mount Oxide Region (Special)	[1]DERRICK, G.M. SWEET, I.P. [2]HUTTON, L.J. [2]WILSON, I.H. [5]PERKINS, W.G.
6859	Myally	[2]WILSON, I.H. [2]GRIMES, K.G. [1]DERRICK, G.M.
6958	Coolullah	[2]WILSON, I.H. [2]GRIMES, K.G.
*7461, part 7462	Gilbert River Region (Special)	MACKENZIE, D.E. HENDERSON, G.A.M. [2]WARNICK, J.V.

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Parts of 5963, 5964, 6063, 6064, 6163, 6164.	Abner Range Region (Special)	JACKSON, M.J.
6758 and part 6658	Mammoth Mines - part Undilla (Special)	[2]HUTTON, L.J. [2]WILSON, I.H. [1]DERRICK, G.M. SWEET, I.P. [5]PERKINS, W.G.
7361, part 7362	Croydon Region (Special)	HENDERSON, G.A.M. MACKENZIE, D.E. [2]WARNICK, J.V.
7460, parts 7459, 7360	Esmeralda Region (Special)	MACKENZIE, D.E. HENDERSON, G.A.M. [2]WARNICK, J.V.

SPECIAL MAPS

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1:12 500 000	Coal Resources (Published by Division of National Mapping)	WELLS, A.T. HULEATT, M.B.
*1:5 000 000	Geology of Australia (Compilation by BMR for 3rd Series, Atlas of Australian Resources, being produced by Division of National Mapping)	D'ADDARIO, G.W. PALFREYMAN, W.D. STEWART, A.J. [1,2]BULTITUDE, J.M. CHAN, R.A.
	Commentary in preparation	PALFREYMAN, W.D.
1:2 500 000	Great Artesian Basin Wire-line-logged water wells	HABERMEHL, M.A. MORRISSEY, J.A.
1:1 000 000	Geophysics of the Officer Basin, Western Australia	JACKSON, M.J.
1:1 000 000	Geology of the Officer Basin, Western Australia	JACKSON, M.J. [1]VAN DE GRAAFF, W.J.E.
1:500 000	Geology of the Ngalia Basin	WELLS, A.T.
1:500 000	Solid geology and geophysics of the Ngalia Basin	WELLS, A.T.
*1:50 000	Geology of Canberra, Queanbeyan & environs (with notes)	HENDERSON, G.A.M.

WITH EDITORS

1:10 000 000	Geology of Australia. (Compilation only, for geological map of the southwest quadrant, being produced by USGS for the Circum-Pacific Map Project)	D'ADDARIO, G.W. PALFREYMAN, W.D. [1]JONGSMA, D. MIKOLAJCZEK, A.J.
1:1 000 000	Geology of the Canning Basin (2 sheets)	TOWNER, R.R. GIBSON, D.L.
1:10 000	ACT engineering geology: Belconnen (with notes)	HENDERSON, G.A.M.
1:10 000	ACT engineering geology: Central Canberra (with notes)	HENDERSON, G.A.M.
1:10 000	ACT engineering geology: Woden-Weston Creek (with notes)	HENDERSON, G.A.M.

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1:500 000	Geology of the southern Prince Charles Mountains (notes included on map face)	TINGEY, R.J.
1:10 000	Central Great Barrier Reef Reconnaissance Maps. Surficial Cover Facies.	RADKE, B.M. HEIGHWAY, K. DAVIES, P.J. MARSHALL, J.F. WEST, B.

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	Commentary by	[1]DERRICK, G.M.
*1:10 000 000	Petroleum and oil shale	WILFORD, G.E.
*1:10 000 000	Sedimentary sequences	WILFORD, G.E. DOUTCH, H.F. BROWN, C.M.

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	Commentary on the 1:10 000 000 surface drainage and continental margin	D'ADDARIO, G.W. JONES, H.A.
1:10 000 000	Coal	WELLS, A.T.
	Commentary	WELLS, A.T.

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	Commentary on the 1:10 000 000 Cainozoic cover and weathering	D'ADDARIO, G.W.

RECORDS

MF (with numbers) below the Record number indicates that the Record is issued in microfiche form; the MF number is that of the microfiche.

ISSUED

1979/87	HENDERSON, G.A.M.	The geology of the Canberra-Queanbeyan 1:50 000 map area.
1980/30	TOWNER, R.R. GIBSON, D.L.	The geology of the onshore west Canning Basin, Western Australia.
1980/39	[1]ROSSITER, A.G. [1]SCOTT, P.A.	Stream-sediment geochemistry of the Seigal and Hedleys Creek 1:100 000 Sheet areas, northern Australia.
1980/44	WARREN, R.G.	Summary descriptions of mineral deposits by commodities in the Alice Springs 1:250 000 Sheet area, Northern Territory.
1980/45	WARREN, R.G.	The Arunta Block in the Huckitta 1:250 000 Sheet area, a review of data to June 1980.
1980/57	LORENZ, R.P. ABELL, R.S.	Bibliography of the geology of the ACT and environs.
1980/61	SIMPSON, C.J.	Georgina Basin Project.
1980/63 MF152	STEWART, A.J. OFFE, L.A. GLIKSON, A.Y. WARREN, R.G. BLACK, L.P.	Geology of the northern Arunta Block, Northern Territory.

1980/65	PLUMB, K.A.	Report on Symposium on Qinghai-Xizang (Tibet) Plateau, Beijing and Southern Tibet, May-June, 1980.
1980/67	TRUSWELL, E.M. ABELL, R.S.	Abstracts. Cainozoic evolution of continental southeast Australia. CECSEA Conference held in Canberra, November 1980.
1980/67	BROWN, C.M.	Abstract. Tertiary coals in the Murray Basin.
1980/74	SIMPSON, C.J.	Georgina Research for the period April-September 1980.
1980/76	SWEET, I.P. MOND, A.	The geology of the Carrara Range region, Northern Territory.
1980/81	1GOLDSMITH, R.C.M.	Lanyon trunk sewer, ACT - engineering geology of proposed Pine Island tunnel and excavation conditions for the pipeline route under Murrumbidgee Park Drive.
1980/82	PERRY, W.J.	Murray Basin Hydrogeological Project Progress Report 4 for half-year ending 30 September 1980.
1980/83	1PURCELL, D.C.	Stromlo-Higgins bulk supply main - Stromlo tunnel section. Engineering geology completion report 1977.

1981/4	COLWELL, J.B. JONES, H.A. DAVIES, P.J.	Initial results of Sonne cruise SO-15 on the east Australian continental shelf, September-November 1980.
1981/5	[1]PURCELL, D.C. [1]VANDEN BROEK, P.H.	Ginninderra sewer tunnel, ACT engineering geology completion report, 1979.
1981/6	ABELL, R.S.	Notes to accompany the 1:25 000 scale geological field compilation sheets of the Canberra 1:100 000 Sheet area.
1981/11		Abstracts 10th BMR Symposium, Canberra, 5-6 May 1981. For contributions by Geological Branch officers see under BMR JOURNAL OF AUSTRALIAN GEOLOGY AND GEOPHYSICS Vol. 6(3).
1981/11	OZIMIC, S.	The use of diagenetic features for evaluating reservoir quality, Sydney Basin.
1981/12	OZIMIC, S.	Stratigraphic drilling in the Cretaceous Toolebuc Formation in the southern and eastern Eromanga Basin, 1980.
1981/13	JACOBSON, G.	Water supply for the proposed secondary school at Matewoulou, Esperitu Santo, Vanuatu.
1981/14	SHERATON, J.W.	Chemical analyses of rocks from East Antarctica.

1981/15	DENHAM, D. KENNEDY, K.M. JOHNSON, R.W.	Review of BMR activities in the fields of earthquake seismology and geomagnetism.
1981/20	PLUMB, K.A.	McArthur Basin Research, July-December, 1980.
1981/23	STEWART, A.J. [2]WILLIAMS, I.R. [2]ELIAS, M.	Notes on the preliminary Youanmi 1:250 000 series map, Western Australia.
1981/24	PLUMB, K.A.	Workshop: Comparison of the Cuddapah Basin, India and the Adelaide Geosyncline, Australia. Report of overseas visit - January 1981.
1981/25	SPARKSMAN, G.F.	Road gravel investigation, Block 64, Tennant, ACT.
1981/30	PERRY, W.J.	Murray Basin Hydrogeological Project Progress Report 5 for half-year ending 31 March 1981.
1981/31	JACOBSON, G. TAYLOR, F.J.	Hydrogeology of Tarawa atoll, Kiribati.
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1981/35	MACIAS, L.F.	Stability analysis of the southwestern slope of Tuggeranong Hill, ACT, 1977.

1981/39	NEEDHAM, R.S.	A tabulated presentation of metallic mine and prospect data for the Pine Creek Geosyncline, NT.
1981/50	PLUMB, K.A.	McArthur Basin research, January-June, 1981.

WITH EDITORS

1980/24	[1]HUTCHISON, D.S. [1]NORVICK, M.	Geology of the north Sepik region, Papua New Guinea.
1980/75	KENNARD, J.M.	Stratigraphic field sections and drillhole logs of the Arrinthrunga Formation, Georgina Basin, central Australia.
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1981/34	TINGEY, R.J. (Compiler)	Geological work in Antartica 1969 - The Prydz Bay-Amery Ice Shelf-Prince Charles Mountains area.
1981/36	GLIKSON, A.Y. [2]HICKMAN, A.H.	Geochemistry of Archaean volcanic successions, eastern Pilbara Block, Western Australia.
1981/38	OZIMIC, S.	Stratigraphic drilling in the Cretaceous Toolebuc Formation in the Charleville district, southern Queensland, June 1981.

1981/41	STUART-SMITH, P.G. WALLACE, D.A. [2]ROARTY, M.J.	Geology of the Mary River/Point Stuart 1:100 000 Sheet areas, NT.
1981/43	TINGEY, R.J. SHERATON, J.W. [4]ENGLAND, R.N.	Geological work in Antarctica 1973 - the southern Prince Charles Mountains.
1981/44	CRUIKSHANK, B.I.	Soil and stream-sediment geochemical data Araluen 1:100 000 Sheet area, New South Wales.
1981/47	WALLACE, D.H. NEEDHAM, R.S. STUART-SMITH, P.G. [2]ROARTY, M.J.	McKinley River 1:100 000 Sheet area, data Record.
1981/48 MF173	WELLS, A.T.	A summary of coal occurrences in Australian sedimentary basins.
1981/51	JACOBSON, G. SCHUETT, A.W.	Groundwater seepage and the water balance of Lake Windermere, Commonwealth Territory of Jervis Bay.
1981/52	MACKENZIE, D.E. HENDERSON, G.A.M.	Gilbert River 1:100 000 geological sheet: catalogue of preliminary field data compilation sheets.
1981/53	[1]WILSON, E.G. [5]TRAND, G.	Queen Street cable tunnel, Melbourne: engineering geology completion report, 1981.

1981/55	[1]WILSON, E.G. [5]TRAND, G.	Lonsdale Street cable tunnels, Melbourne, Victoria: engineering geology completion reports, 1981.
1981/56	BARLOW, A.J. LORENZ, R. MCGEEHAN, M. MODRAK, K.	Computerised bibliographic databases in the BMR.
1981/60	O'BRIEN, P.E.	Permian sediments beneath the Murray Basin.
1981/61	KELLETT, J.R.	Hydrogeological investigations in two basins at Lanyon, ACT, 1974-1976.

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	[1]DERRICK, G.M. [2]WILSON, I.H.	Geology of the Alsace 1:100 000 Sheet area (6858), Queensland.
	OZIMIC, S.	Stratigraphic drilling in the Cretaceous Toolebuc Formation in the southeastern Eromanga Basin, Queensland, 1981.
	SHAW, R.D. [4]FREEMAN, M.J. OFFE, L.A. [1]SENIOR, B.R.	Geology of the Illogwa Creek 1:250 000 Sheet area, central Australia - preliminary data 1979-80 surveys.
	SHAW, R.D. WARREN, R.G. OFFE, L.A. [4]FREEMAN, M.J. [4]HORSFALL, K.	Geology of the Arunta Block in the southern part of the Huckitta 1:250 000 Sheet area, central Australia - preliminary data, 1980 survey.

TINGEY, R. (Compiler)	Rb-Sr geochronological data from Antarctica resulting from the studies of Dr. P.A. Arriens.
2WITHNALL, I.W. MACKENZIE, D.E.	Precambrian stratigraphy, metamorphism, and structure of the North Head-Forest Home region, north Queensland.

PROFESSIONAL OPINIONS (Issued)

Geol. 80.020	EVANS, W.R.	Groundwater resources of the eastern portion of Kowen Forest, A.C.T.
Geol. 80.021	JACOBSON, G.	Proposed timber treatment plant at Hume, A.C.T. - possible groundwater pollution.
Geol. 80.022	BURGER, D.	Report of field trip to Croydon, Queensland.
Geol. 81.001	EVANS, W.R.	Groundwater resources of the Federal Golf Course, Red Hill, A.C.T.
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Geol. 81.004	TRUSWELL, E.M.	A palynological examination of samples from Aquitaine Minerals Pty Ltd corehole WBN 5003, Bonaparte Gulf Basin.
Geol. 81.005	NICOLL, R.S.	Evaluation of conodont color alteration from selected subsurface samples from the Amadeus Basin, central Australia.
Geol. 81.006	JACOBSON, G.	Canberra City groundwater pollution - operation of the recovery system August 1979 - March 1981.

Geol. 81.007	JACOBSON, G.	Comments on report "Pichit Groundwater Study, Thailand".
Geol. 81.008	HABERMEHL, M.A. PERKIN, D.J.	Comments on Honeymoon Uranium Project - Final Environmental Impact Statement.
Geol. 81.009	TRUSWELL, E.M.	Palynology of two outcrop samples from Lerderderg River, Victoria.
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Geol. 81.014	NICOLL, R.S. JONES, P.J.	Lower Carboniferous conodont and ostracod biostratigraphy and the lithofacies of the Bonaparte Gulf Basin, northwestern Australia.
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Geol. 81.016	KELLETT, J.R.	Water supply for Gold Creek homestead.

Geol. 81.017	ABELL, R.S. TAYLOR, F.J.	Hydrogeological/geophysical investigations of Norfolk Island, 1981.
Geol. 81.018	KELLETT, J.R.	Floodway subsidence and failure of pipe joints - Isaacs Trunk Stormwater system.
Geol. 81.019	TRUSWELL, E.M.	Palynology of a carbonaceous clay from Norfolk Island.
Geol. 81.020	NICOLL, R.S.	Irian Jaya conodont age determinations, 1981.
Geol. 81.021	SHERGOLD, J.H.	Palaeontological determinations of phosphatic samples from the Undilla and Riversleigh 1:100 000 Sheet areas, Georgina Basin.