REPORT 196

Geological Branch
Summary of Activities
1976

DEPARTMENT OF NATIONAL RESOURCES
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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Geological Branch Summary of Activities 1976

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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
DIRECTOR: L. C. NOAKES
ASSISTANT DIRECTOR, GEOLOGICAL BRANCH: J. N. CASEY

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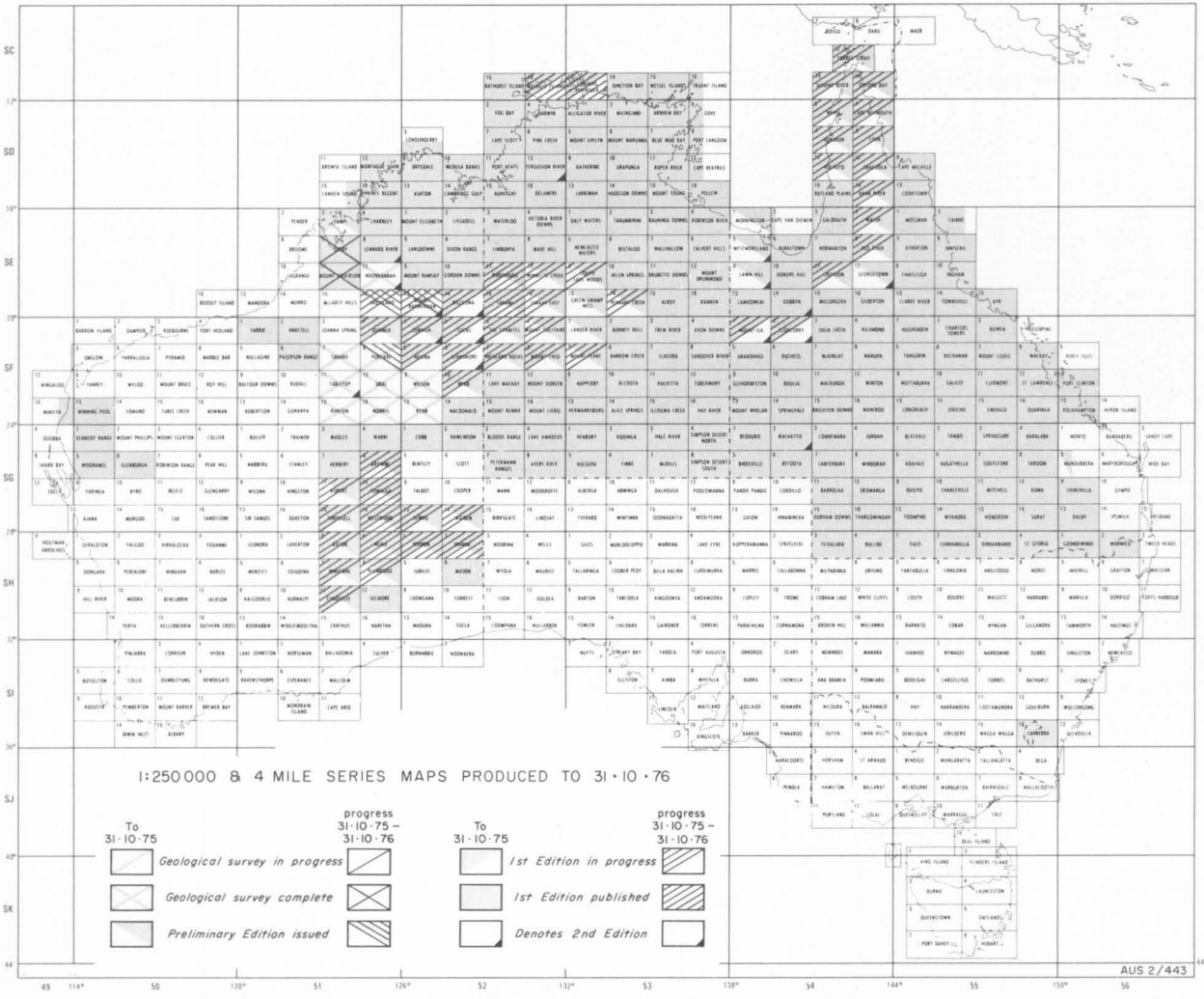


ANTARCTICA

1:250 000 SERIES MAPS PRODUCED TO 31·10·76

FIELD WORK IN PROGRESS TO 31·10·76

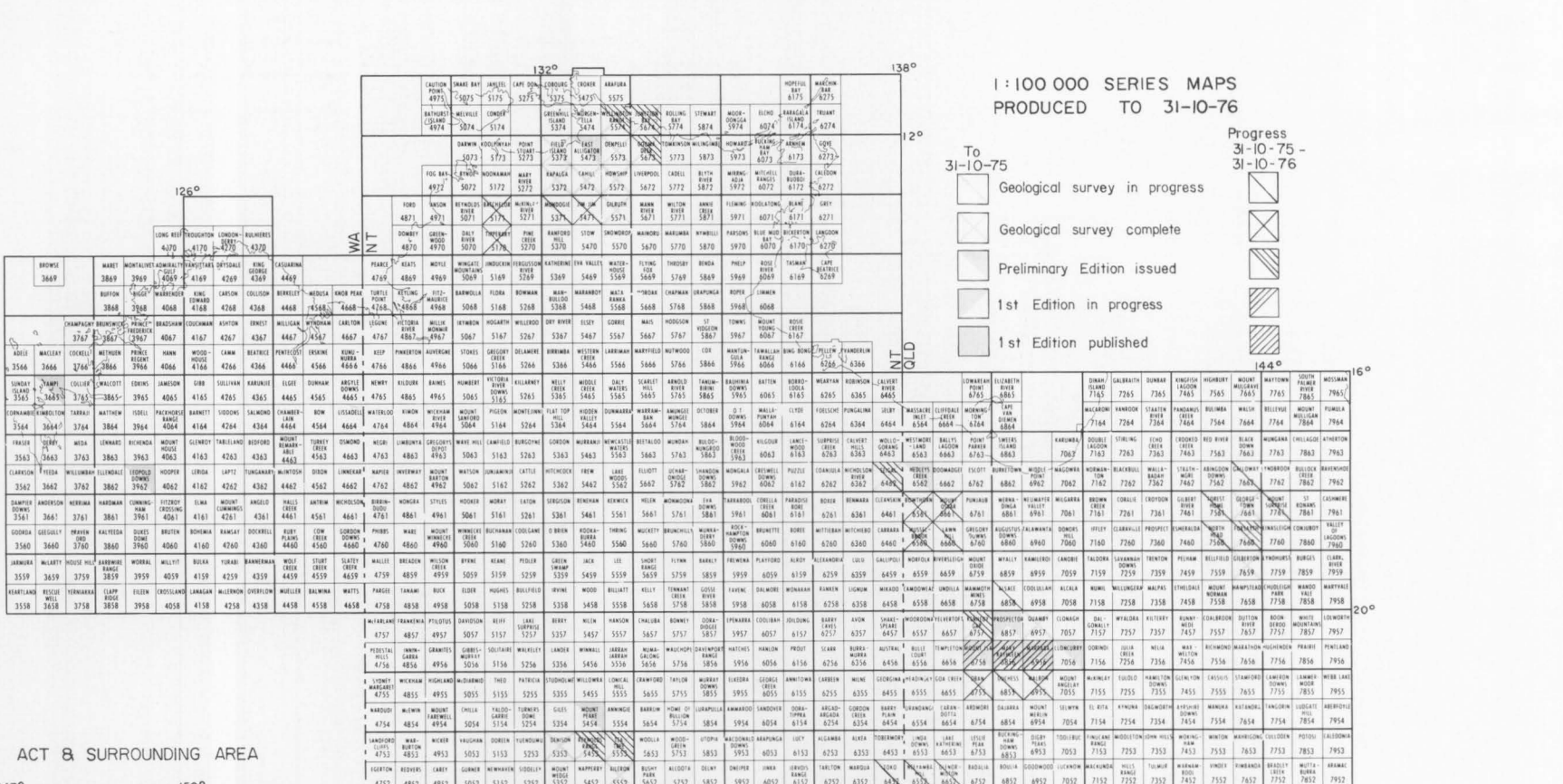
AKER PEAKS
CAPE BORLEY
CHURCH MOUNTAIN
DISMAL MOUNTAINS
HANSEN MOUNTAINS
McLEOD NUNATAKS
MOUNT CODRINGTON
MOUNT RIISER-LARSEN
NYE MOUNTAINS
PROCLAMATION ISLAND
RAYNER PEAK
SANDERCOCK NUNATAKS
SCULLIN MONOLITH
SIMPSON PEAK
TANGE PROMONTORY

PRELIMINARY EDITION ISSUED

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

SHEETS ISSUED 31·10·75 - 31·10·76

MOUNT MENZIES
MOUNT TWIGG
WILSON BLUFF


1 : 100 000 SERIES MAPS
PRODUCED TO 31-10-76
To 31-10-75
Progress 31-10-75 - 31-10-76
Geological survey in progress
Geological survey complete
Preliminary Edition issued
1st Edition in progress
1st Edition published
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GENERAL SUMMARY

SEDIMENTARY SECTION

by

G.E. Wilford

The 25th International Geological Congress, held in Sydney in August, occupied most staff to varying degrees throughout the year. Involvements included secretarial assistance, arranging and running excursions, preparing guide books, organizing symposia, and the presentation of papers. Consequently the scale of the Section's other activities was reduced. Fieldwork was mainly restricted to mapping relatively small areas in the Canning and Georgina Basins and in the Canberra area, and to investigations of ancient beach sands in southeast South Australia and to submarine reef stratigraphy in the southern Great Barrier Reef (Fig. S.1).

The Canning Basin mapping, in co-operation with the Geological Survey of Western Australia, resulted in the revision of the geology of the Derby and Mount Anderson Sheet areas. Previously mapped units were subdivided, more accurately delineated and further sedimentological, structural and palaeontological information collected. Reporting continued on earlier fieldwork undertaken in the Wiso, Carpentaria, Karumba, Ngalia, and Officer Basins; Bulletins and 1:1 000 000 or 1:500 000-scale geological maps, explanatory notes and 1:250 000-scale geological maps, and papers on these areas are scheduled for completion by mid-1977. A re-interpretation of geophysical information from the southern part of the Wiso Basin confirmed earlier tentative ideas that the Palaeozoic sequence thickens to perhaps 1000 m in the eastern part of the Lander Trough.

Advances were made in the multi-disciplinary study of the Georgina Basin, particularly in the interpretation of the environment of deposition of the many Lower Palaeozoic units and their correlation with neighbouring areas. Significant was the confirmation that evaporitic conditions had prevailed in the basin at times.

Revision mapping of the Canberra 1:250 000 Sheet area, in co-operation with the Engineering Geology Group and the Geological Survey of New South Wales, continued. Four of the six 1:100 000 Sheet areas have been mapped, Tantangara and Brindabella by BMR, Braidwood and Michelago by GSNSW. Mapping of the Canberra Sheet by BMR started in 1976 and it is planned to map the Araluen Sheet area in co-operation with GSNSW starting in 1977. Detailed petrographic and geochemical studies have indicated that in the Ordovician of the Kiandra area volcanic rocks of island-arc tholeiitic type are younger than those with high-K/calcalkaline affinities. Silurian acid volcanic rocks, despite intense alteration, have been subdivided successfully on petrographic grounds. A new fauna and flora was discovered in a probable Middle Devonian continental unit.

Manganese nodules were dredged from eight places on the ocean floor southwest of Perth during a cruise on HMAS Diamantina in co-operation with Monash University. The nodules, from depths of 4300 to 5000 m, contain combined copper, nickel and cobalt contents that are about half those of nodules from the accumulations in the northeast Pacific.

Seven reefs in the Capricorn/Bunker Groups of the southern Great Barrier Reef were studied using geophysical and diving techniques. Data were collected which should define the nature of the karst platform on which reef growth took place in Holocene time and indicate the growth rate of the reefs, their lithification, and potential for metal accumulation and dispersion.

Experimental work on the formation of ooids, together with field observations on accumulations in the Great Barrier Reef, indicate that organic material is important in their formation.

The Palaeontological Group has a staff of 22 of whom 15 are specialists in particular fossil groups. In addition to describing, curating and expanding the national fossil collection, the Group are responsible for almost all palaeontological support for field mapping projects and for palaeogeographic interpretation of the fossil record. During the year collections from the Wiso, Canning and Georgina Basin parties, from the Canberra mapping projects and from Papua New Guinea were identified and dated. Work on the refinement of time scales continued using Australian and oversea material, and collections were made in New Zealand and in the Sula Islands, Indonesia to assist in this work. The Group's systematic studies included Precambrian microfossils and stromatolites, Early Palaeozoic trilobites, Late Palaeozoic conodonts, fishes, molluscs, and ostracods, Mesozoic molluscs, Cretaceous floras, Cainozoic floras, mammals, foraminifera and nannofossils.

THE BAAS BECKING GEOBIOLOGICAL RESEARCH LABORATORY

by A.R. Jensen

The Baas Becking Geobiological Research Laboratory was established in 1964 to undertake investigations relevant to the problem of the origin of sedimentary stratiform sulphide deposits. The microbiologists, geologists, chemists, and technical officers involved with the Baas Becking program are either from CSIRO Minerals Research Laboratories, BMR, or they are employed by CSIRO and paid from a Trust Fund sponsored jointly by BMR, CSIRO, and the Australian Minerals Industry Research Association.

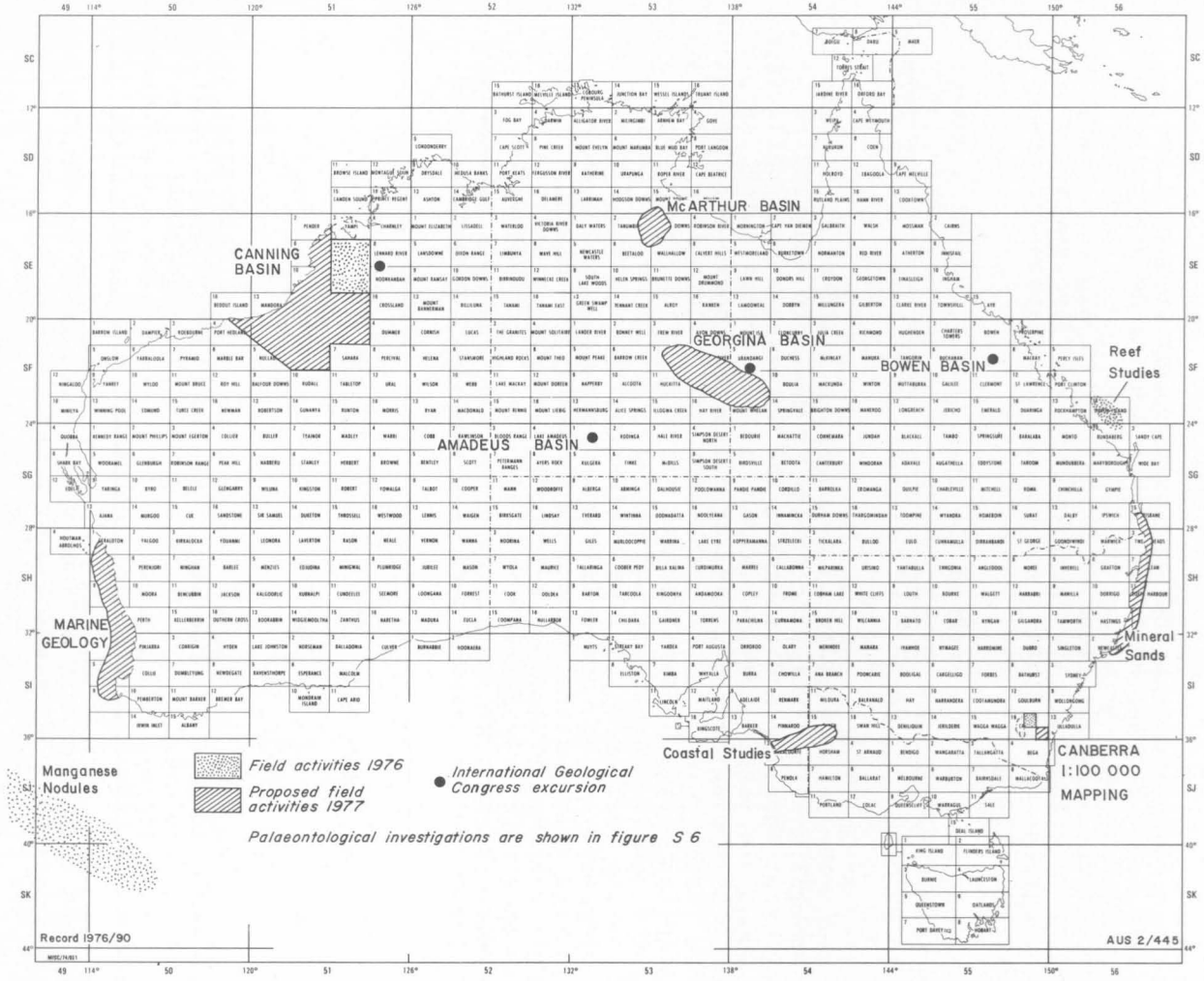

Fig. S1. Sedimentary Section field activities.

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During 1976, geochemical and petrological studies of base metal sulphide deposits in the Lachlan Geosyncline (Woodlawn), and in the Pine Creek Geosyncline (Mount Bonnie, Woodcutters, and Browns) were completed. Studies commenced of mineralization in the McArthur Basin (Redbank) and the Georgina Basin. A model based on the mixing of hydrothermal solutions and metal-rich volcanic fluids has been proposed for Woodlawn as a result of the studies. In the Pine Creek Geosyncline, the results suggest that in the case of the deposit at Mount Bonnie, metals and sulphur were derived from the leaching of basic sills, whereas at Woodcutters the sulphides were derived from organic-rich carbonate rocks. The Browns deposit was formed by the interaction of both Mount Bonnie and Woodcutters type processes. A start has been made on an investigation of the mineralization at the Redbank copper project, and of carbonate rocks from the Georgina Basin to determine the way in which lead and zinc occur.

Studies of microfossils and cherts from the McArthur Basin were completed during the year. The results suggest that bacteria played an indirect role in the formation of the HYC deposit and that the study of fossil microbiota of this age does have potential for biostratigraphic zonation and palaeoecological analysis.

Stable isotope studies of Archaean sedimentary rocks and ore bodies have been undertaken on a large number of samples from Australia and overseas, mainly to assess the likely sources of sulphide, carbonate and reduced carbon. In no case has there been any clear evidence for biogenic derivation of sulphides. Analysis of sedimentary rocks and gold and nickel mineralization from the Yilgarn Block in Western Australia, and gold deposits of the banded iron-formation of Rhodesia, suggests that the sulphides have been derived from a magmatic source. The reduced carbon in the Western Australian rocks, and from the Archaean succession in Greenland, appears to be syngenetic, the results suggesting the possibile existence of biological activity. At least some of the carbon, however, has been produced by abiological processes. Values obtained from the analysis of carbonate in the Archaean rocks suggest a marine source in some cases, and in other cases derivation from magmatic sources either as primary CO_2 or oxidation of magmatic methane. Abiological sulphate reduction at temperatures around 200°C was indicated by the result of the stable isotope studies of Pb/Zn mineralization in Lower Palaeozoic rocks from Laisvall, Sweden.

Reduction of sulphate as a factor in sulphide mineralization has continued to be studied both in the field and by laboratory experiments. A collaborative project with the University of Stockholm on waters and sediments of the Baltic Sea is providing information on the kinetics of sulphur turnover in

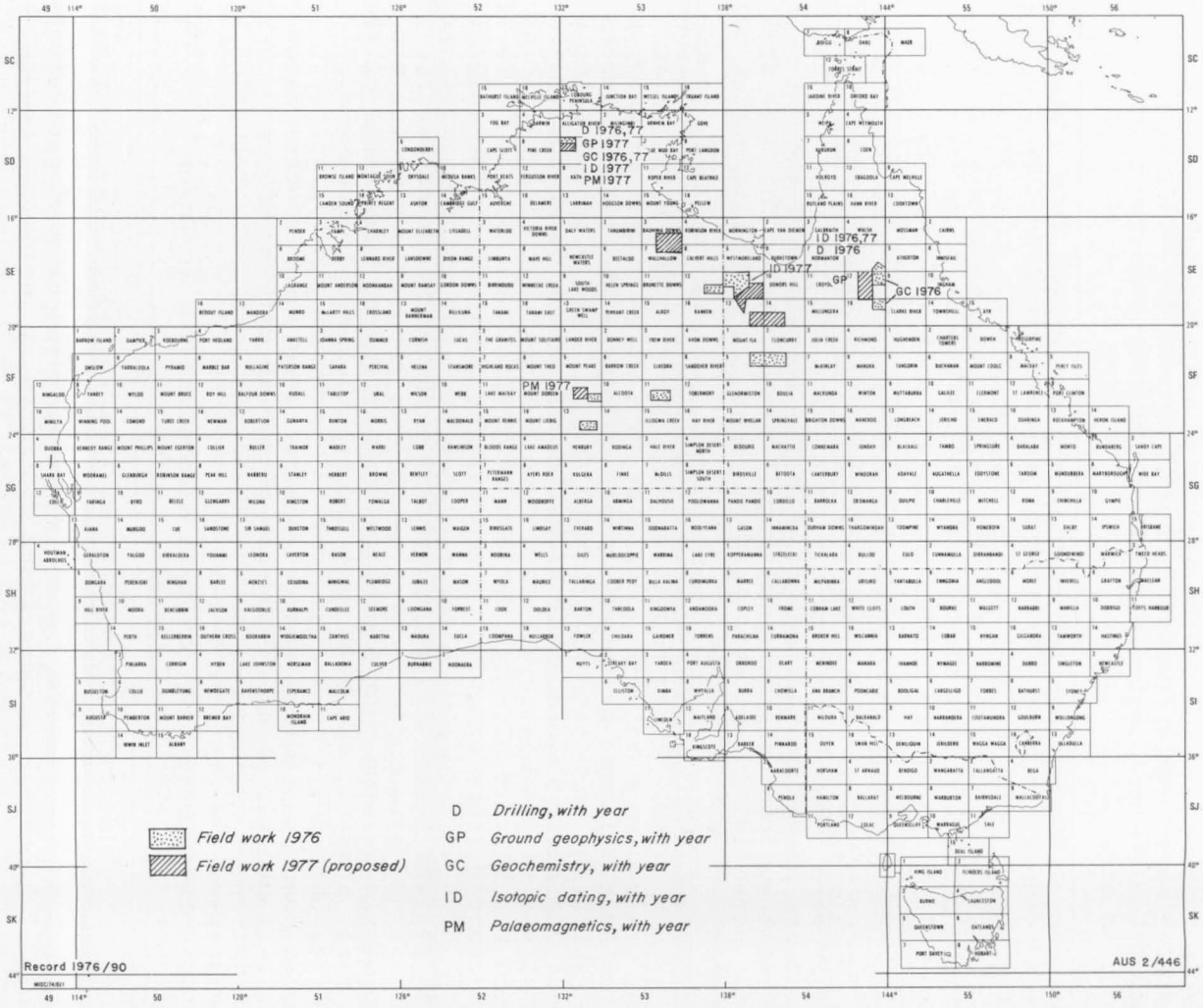

Fig. M1. Geological mapping and related activities, Metalliferous Section.

modern sedimentary environments and on accompanying changes in stable isotope distribution. A similar approach will be applied to environments in Spencer Gulf where attempts will be made to evaluate the importance in mineralization and isotope fractionation of compounds such as thiosulphate which laboratory experiments have shown to be significant products of microbial sulphur metabolism. In view of the Laboratory's future studies in Spencer Gulf, a review of recent information of relevance to the geomicrobiology of modern sedimentary environments was undertaken.

Abiological sulphate reduction, a potentially important reaction in hydrothermal solutions, has been shown to take place at 220°C in mixtures of sulphate, sulphur, water and coal or coal extracts.

METALLIFEROUS SECTION

by R.G. Dodson

The 25th IGC held in Sydney 16-25 August imposed a considerable workload on the Metalliferous Section - participation included presentation of papers at the Congress, and organization and guidance of excursions (5A, 5C, 44C, 47C). Despite this, most programmed objectives were attained and work continued on about forty projects; Fig M1 shows areas where fieldwork was carried out.

Fieldwork in central Australia was confined to visits to key localities within the Arunta Block and adjacent areas. Fresh confirmation of the subdivision of the Arunta Block proposed in last year's Annual Summary was obtained. As part of an investigation of the distribution of the numerous small mineral occurrences in the Arunta Block an orientation geochemical survey was made over copper and tungsten prospects. In the Alligator River uranium province fieldwork consisted of semi-detailed mapping in parts of two 1:100 000 Sheet areas and drilling for stratigraphic information about subsurface rock mantled by superficial deposits in another area.

In Antarctica overall priority was given to the surveyors of the 1975-6 ANARE Summer Expedition. However, two BMR geologists attached to the survey parties were able to visit numerous scattered outcrops in Enderby Land and to make a collection of sapphirine-quartz-bearing rocks. Osumilite, a rare complex K-Fe-Mg aluminosilicate mineral, was identified in a specimen collected during the brief field season.

In Queensland fieldwork continued on the Mount Isa/Cloncurry, Duchess, Lawn Hill and Georgetown projects. In the Mount Isa/Cloncurry area a reconnaissance overview of the Alsace 1:100 000 Sheet area was made and semi-detailed mapping continued in the Duchess, Malbon and Oban 1:100 000 Sheet areas by a joint BMR-GSQ field party. The Precambrian rocks have been subdivided into three main groups: an eastern succession and a western succession of predominantly stratified sequences, separated by the Kalkadoon Leichhardt Basement Block. Copper minerals are widespread, occurring in basic bodies and shear zones of the Argylla Formation, shear zones of the volcanic member of the Marraba Volcanics and black shale at the base and the top of the Kuridala Formation. Fieldwork in the Lawn Hill area was completed for the Bowthorn, Mount Oscar and Musselbrook 1:100 000 Sheet areas; Lawn Hill is about two-thirds complete. The sequence here can be broadly correlated with that of Westmoreland to the north, the generalized sequence in each area being a basement of volcanics and granite overlain unconformably by a sandstone/carbonate/sandstone/shale sequence. The Georgetown project, a multidisciplinary venture, embraces semi-detailed geological mapping, geochemical and geophysical surveys and geochronological investigations, supported by a BMR drilling party. Fieldwork included the completion of the geological mapping of the Newcastle Range, the ground checking of magnetic anomalies, and the investigation of a mineralized copper and molybdenum porphyry-type prospect, Mount Turner.

In Papua New Guinea, BMR is now concerned with completion of the reporting of such ventures as the North Sepik and New Britain projects. Four BMR geologists were seconded to temporary specialist positions in the Irian Jaya project for the Overseas Aid Section of the Department of Foreign Affairs. The main objective of the project is the compilation of basic information on the geology of Irian Jaya, in conjunction with the Geological Survey of Indonesia.

Study of volcanicity and ore genesis in the volcanic areas of Papua New Guinea has led to the writing of several reports on the petrology and tectonic settings of Late Cainozoic volcanoes. In addition to these reports the recently published G.A.M. Taylor Memorial Volume entitled 'Volcanism in Australasia' (edited by R.W. Johnson) includes twenty-eight papers on a wide range of topics by authors from BMR, Universities, Geological Surveys and other organizations.

The Petrological, Geochemical and Geochronological Laboratories were involved in several major and some minor projects. The study of granulites from the Arunta Block continued and the joint BMR-GSWA investigation of the geochemistry of rocks from the Pilbara area was extended by a joint field visit with a member of the CSIRO Division of Mineralogy. Twenty-two komatiite samples from the Barberton Mountainland, South Africa, have been analysed and interpreted as part of an Archaean tectonic-geochemical study.

A geochemical investigation was carried out on felsic gneisses, mafic gneisses, charnockite and other granitic rocks and mafic dyke rocks from MacRobertson Land, Antarctica.

A petrological and chemical investigation was made of the mineralization of the Alligator Rivers uranium field to try to establish the provenance, the temperature of formation and the environmental conditions of ore deposition.

An investigation of kimberlites and rocks of kimberlitic affinities, although in its early stages, indicates that the known Australian kimberlites belong to three age groups: Permian, Jurassic and Quaternary.

A regional stream sediment geochemical survey was carried out over part of the Georgetown area; results of the 1975 geochemical survey of the Westmoreland and Georgetown areas are being processed together with previous reports of surveys of the Cullen Granite and the Tennant Creek Goldfield.

The Geochronology Group continued to support several BMR projects using Rb-Sr isotopic dating techniques. A project in western Tasmania will be written up in collaboration with members of the Tasmanian Geological Survey. The U-Pb zircon technique has shown that earlier Rb-Sr results in the Mount Isa region are 10 to 15 percent too young.

GEOLOGICAL SERVICES SECTION

by E.K. Carter

All groups in the Section were involved to some extent in the preparations for, and conduct of, the 25th International Geological Congress, held in Sydney in August 1976, or in associated excursions. The work programs of the Map Editing and Compilation group and the Geological Drawing Office were determined in large measure by publications required to be available for, or in time for, the Congress. Contributions of the Section included preparation for publication of several major maps and many other maps, preparation of text figures and slides for papers, and one guide book, contributions to two excursions, mineral and map displays, and convening of or assisting in the presentation of sessions and other aspects of the Congress and associated scientific meetings.

Staff available for the Section's work program effectively declined by four geologists, four drafting and photographic staff and four field hands. Increasingly through the year senior staff were engaged in forward-planning and other management

tasks. The Section maintained its usual involvement in inter-Survey, inter-Departmental and inter-Bureau information and co-ordination meetings and continued its personnel development activities by participation by its members in courses, workshops and conferences.

Major maps that officers of the Section compiled (some in part only), edited, fair drew, or processed for printing, generally in continuation of the previous year's program were:

1:2½ M geology of Australia (4 sheets)
1:2½ M geology of Northern Territory
1:2½ M Cainozoic of Northern Territory
1:2½ M geology of Papua New Guinea (D.B. Dow, senior compiler)
1:10 M geology of Australia.

Other 1:10 M thematic maps of Australia were compiled.

Production statistics for the Map Editing and Compilation group and the Drawing Office, in summary are:

Maps edited 22: in progress 11
Preliminary edition maps drawn 6: in progress 21
Preliminary edition maps printed 17
Series (1:250 000 and 1:100 000) colour edition maps drawn 17: in progress 17
Special (1:500 000 and smaller scale) colour maps drawn 10: in progress 13
Colour maps printed 37: with printer 31
Black-and-white text figures drawn for publications and Records 1390: in progress 234.

As usual, most of the activities of the Engineering Geology and Hydrology Sub-section related to the development of Canberra and Queanbeyan. Very few services were provided for other regional growth centres but field assistance was given on three overseas projects: Cocos Islands (Home Island) groundwater resources, and Suva water supply and sewerage schemes, Fiji.

Geological services were provided throughout the year during construction of Googong Dam, Queanbeyan River; and in the latter part of the year for the appurtenant facilities - pump station, treatment plant and pipeline to Canberra. Feasibility studies were carried out for two alternative damsites on the Gudgenby River and for thirty-seven reticulation reservoir sites in the Tuggeranong district. The Lanyon Trunk Sewer (5 alternative routes) and two alternative routes for a new Canberra Trunk Sewer were investigated. Construction of Ginninderra Sewer Tunnel will start in December 1976.

An assessment of the regional sand and gravel resources indicated adequate supplies for Canberra development for many years. Possible airport sites and rapid transit routes were examined. The continuing record of the level and water quality of Lake George and groundwater in the ACT region was maintained. Drainage studies in the Isabella Plains and Lanyon areas of the Tuggeranong district were continued; they have contributed substantially to the alleviation of the development problems foreseen.

The group contributed to the geological mapping of the Canberra 1:100 000 Sheet area by mapping in the Sutton-Gundaroo area at a scale suitable also for urban development purposes. Stratigraphic holes were also designed and logged to improve knowledge of the geology of the Canberra area. Follow-up urban development mapping and investigation of specific areas, such as regional centres, was carried out in the Tuggeranong and Gungahlin districts. Work continued on the production of the 1:10 000 scale engineering geology of Canberra series: Coppins Crossing Sheet is with the editor and two other Sheets are being prepared.

The normal work of the Registry of Stratigraphic Names - literature indexing, answering enquiries and issuing variations lists - was maintained during the year. The issue of Fascicule 5h - Australia, General - of the International Stratigraphic Lexicon has made generally available a list of all published Australian stratigraphic names recorded to the end of 1968.

Technical files and the mineral index were maintained and some work was done on compiling for publication reports on the occurrence of three mineral commodities.

In September Museum staff received, on behalf of the Australian Government, the very fine C.V. Latz collection of Australian and foreign display minerals, greatly increasing the size and quality of the Bureau's holdings. A high level of activity was maintained in the field of public information and educational services, by helping visitors to the Museum, including classes of school children, and by presenting displays in Canberra and interstate. Other Museum activities, including identification of specimens, preparation of scientific papers, acquisition of new material, recataloguing of existing holdings and storing of BMR field party collections continued through the year.

SEDIMENTARY SECTION

Head of Section: G.E. Wilford

PROVINCE STUDIES

CARPENTARIA AND KARUMBA BASINS

by

J. Smart

STAFF: H.F. Doutch (to September), J. Smart; K.G. Grimes (GSQ)

The main objectives of the Carpentaria Basin project are to understand the Mesozoic geology of the area (now Carpentaria Basin sensu stricto) and the overlying Cainozoic sequence (now known as the Karumba Basin). The results of the survey have been reported in a series of Records, 1:250 000 geological maps and explanatory notes, papers on specific aspects of the geology, and a bulletin which includes a synthesis of the geology of both basins, an assessment of geophysical data by J. Pinchin (Geophysical Branch), and a 1:1 000 000 geological map.

Field work lasted from 1969 to 1973 and report writing is almost complete. The bulletin is in first draft; 1:250 000 geological maps and explanatory notes covering the area are now published or in press and only Mornington/Cape Van Diemen and Westmoreland Sheet areas are outstanding; both are covered by Preliminary Maps and Records.

Doutch published a paper defining the Cainozoic Karumba Basin as a separate entity from the Mesozoic Carpentaria Basin. He left the project in September to take up an ADAA appointment in Bangkok for 2 years. Smart published a paper on the beach ridges of western Cape York Peninsula, a joint paper (with G. Pettifer, Geophysical Branch) on resistivity methods in groundwater search, and prepared a note on late Pleistocene sea levels in the Gulf of Carpentaria for outside publication.

GEORGINA BASIN

by

E.C. Druce

STAFF: E.C. Druce, B.M. Radke, J.J. Draper, J. Kennard, J.H. Shergold, M.R. Walter, P. West (ANU), R. Fortey (British Museum), K. Heighway.

The Georgina Basin Project aims to improve knowledge of the geological history of the basin, particularly by elucidating the lithological and geochemical variations of units and their interrelationships. It includes a detailed study of the biota to

aid in correlation and palaeoenvironmental and palaeogeographical reconstructions. The result will aid exploration for hydrocarbons, phosphate, and base metals.

Field work during 1976 was limited by a commitment of the project to organize and run International Geological Congress Excursion 4C. E.C. Druce and J.H. Shergold were co-leaders of this excursion and B.M. Radke, J.J. Draper and J. Kennard acted as guides. However, some time was spent on further elucidating (i) the Precambrian and Early Cambrian sediments in the Huckitta, Alcoota, Barrow Creek and Mount Peake 1:250 000 Sheet areas (M.R. Walter); (ii) the Middle Cambrian units (Arthur Creek and Marqua Beds) of the southern part of the Basin, Tobermory and Huckitta 1:250 000 Sheet areas (P. West), (iii) the depositional environment of the Ninmaroo Formation (B.M. Radke), (iv) the regional variations of the Arrinthrunga Formation (Upper Cambrian) - its depositional environment and its extent in space and time (J. Kennard) and its stratigraphic relations to other units (J. Kennard and P. West), (v) the trilobite faunas of the Datson Member of the Ninmaroo Formation, and the Kelly Creek, Coolibah and Nora Formations, the Carlo Sandstone and the Mithaka Formation (R. Fortey, J. Shergold, J. Draper and E. Druce), (vi) the regional variations of the Nora Formation (E. Druce) and (vii) the nature and geological relationships of the Sun Hill Arkose and Sylvester Sandstone (J. Draper).

Preliminary results indicate that -

1. Upper Precambrian to Lower Cambrian sediments of the southwest Georgina Basin are the platform equivalents of the basinal sediments of the Amadeus Basin, with marine sediments of this age occurring in the Georgina Basin only in northwest-trending low areas that cut across the platform;

2. the unit mapped as the Grant Bluff Formation near Mount Skinner in the Alcoota 1:250 000 Sheet area is a facies varient of the Central Mount Stuart Beds - the unit mapped as the Grant Bluff Formation in the Barrow Creek 1:250 000 Sheet area is younger than, and lithologically different to, the type Grant Bluff Formation;

3. there was no barrier to sedimentation during the Middle Cambrian between the Marqua area (Tobermory 1:250 000)) and the Huckitta area (Huckitta 1:250 000):

4. differences in trilobite faunas in the Middle Cambrian of the southern Georgina are due to rapid lateral changes in depositional environment;

5. sedimentation was possibly continuous during the Early Cambrian in the easternmost part of the Huckitta area;

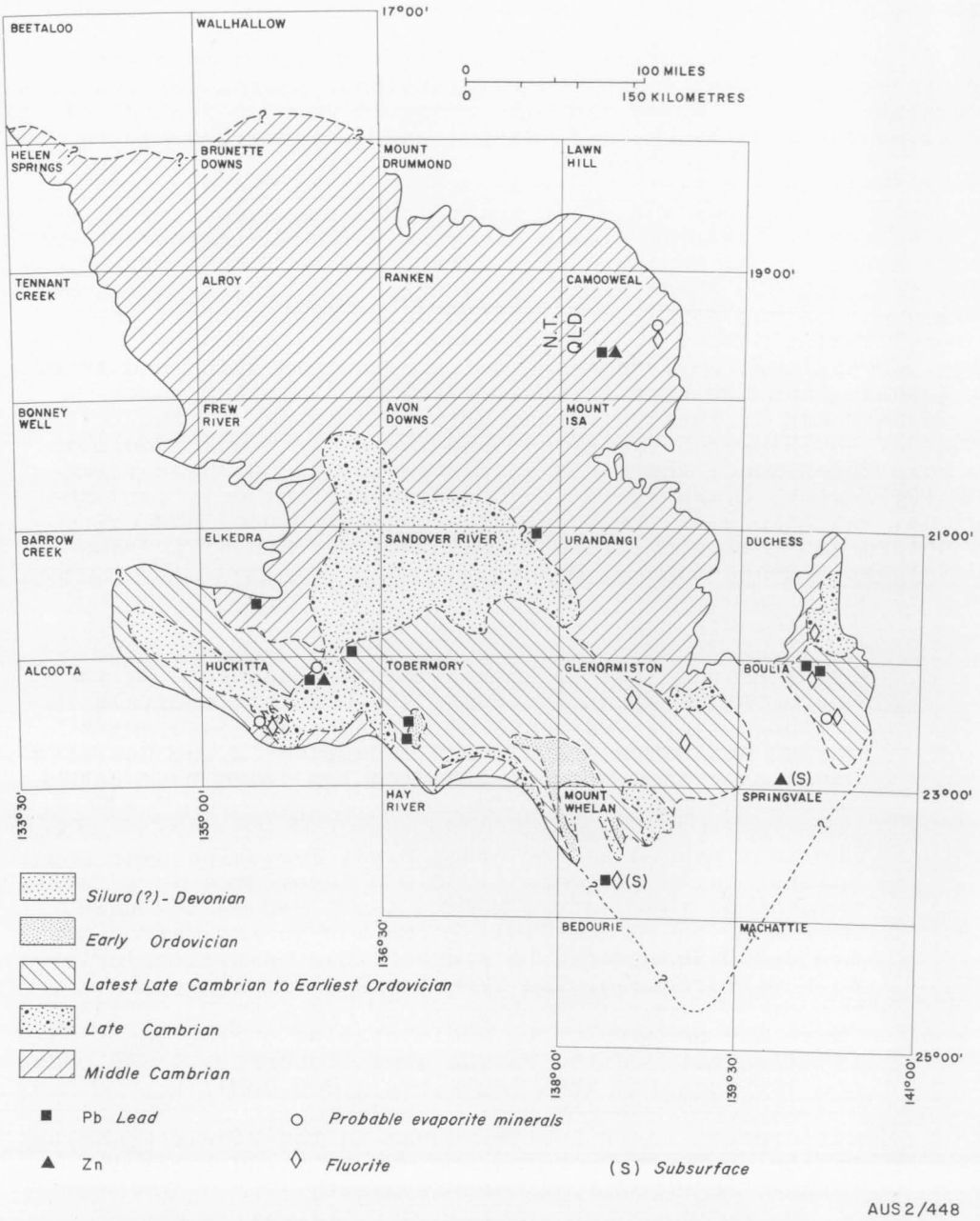

Fig. S2. Generalised geological map and minor mineral occurrences, Georgina Basin.

6. the Arrinthrunga Formation (Upper Cambrian) in the type area consists of shallow-water carbonates including peloidal, clast and ooid grainstones, algal limestones and dolomites and minor bioturbated micritic limestones together with minor fine-grained siliciclastics and minor fluorite;

7. the fine-grained dolomites towards the base of the Arrinthrunga Formation contain casts of a bladed crystal (?gypsum) preserved in chert nodules;

8. sedimentation of the Arrinthrunga Formation was probably marginal to an epeiric sea within subtidal, intertidal and supratidal environments;

9. the type section of the Arrinthrunga Formation is incomplete in that some of the sequence in the upper 350 m is faulted out;

10. the Chatsworth Limestone (Upper Cambrian) in the type area was deposited in a sequence of environments including metasaline restricted intertidal or shallow subtidal pelletal and carbonate mud flats behind a barrier oolite shoal, intertidal or shallow subtidal rippled pelletal flats with migrating sandy carbonate migaripples, and aeolian calcareous dunes;

11. the Ninmaroo Formation (Lower Ordovician) type section contains minor fluorite on the higher parts of Black Mountain (Fig. S2);

12. the Ninmaroo Formation contains casts of tabular crystals in chert layers (?gypsum) and chalcedonic and calcitic nodules associated with breccias which are interpreted as relict anhydrite or gypsum nodules (Fig. S2);

13. the Datson Member of the Ninmaroo Formation at Mount Datson contains up to three trilobite faunas which are probably Arenigian;

14. the Nora Formation contains at least four Arenigian trilobite faunas;

15. the transgression during the deposition of the Nora Formation extended into the Wiso Basin;

16. the Carlo Sandstone and Mithaka Formation comprise a barrier/lagoon bay system and are similar to the Stairway Sandstone in the Amadeus Basin;

17. fish remains occur in the Coolibah and Nora Formations, and the Carlo Sandstone;

18. the Devonian in the Toko Syncline consists of Lower Devonian marine thelodont-bearing beds and Middle to Upper Devonian terrestrial deposits (Cravens Peak Beds);

19. casts of a bladed crystal (?gypsum) are also present in chert beds at the interfingering contact between the Middle Cambrian Age Creek Dolomite and Current Bush Limestone in the Undilla area (Fig. S2).

Continuing geochemical studies are aimed at (i) establishing the geochemical character of various rock units and from this extract maximum environmental information; and (ii) calculating regional background values for Cu, Pb, Zn, Ba, F and P. In addition to this some analyses have been carried out on iron and manganese weathering concentrations to examine their value as mineralization indicators. Preliminary observations on results from the Burke River Structural Belt are:

20. in any particular sample, the HCl-soluble elements (Ca, Mg, Sr, Fe and Mn) appear to be more homogeneously distributed than the whole-rock fraction elements (Cu, Pb, Zn, Ba, F, V, P, and Organic C);

21. anomalous values of Cu, Pb, Zn and Ba exist, mainly associated with concentrations of goethite and manganese oxide developed on rocks of the upper part of the Ninmaroo Formation and the Swift Formation;

22. values of phosphate in the Chatsworth Limestone and Ninmaroo Formation are low;

23. anomalous F values in this area are associated with fluorite, the origin of which is, as yet, unknown;

24. significant geochemical differences exist between the Chatsworth Limestone and the Ninmaroo Formation - the Chatsworth Limestone is enriched in Sr, P, and Mn, and depleted in Ca and Mg relative to the Ninmaroo Formation;

25. the effect of weathering is shown by differences between surface and subsurface samples, and change of values down-hole;

26. random sampling near Noranside lead mine indicates a possible lead dispersion pattern of over 700 m radius.

NGALIA BASIN

by

A.T. Wells

The objective of the project is to synthesise all available geological and geophysical data on the Ngalia Basin. Writing of the Bulletin commenced during the year and the first drafts of the stratigraphy and introductory sections were written. No further field investigations were undertaken apart from a brief visit to uranium-mineralized areas in the Carboniferous Mount Eclipse Sandstone in the northern part of the basin. Uranium concentrations are being explored in this area by Central Pacific Minerals, mainly in the Treuer Range area.

WISO BASIN

by

P.J. Kennewell

STAFF: P.J. Kennewell, M.B. Huleatt (to March, 1976), S.P. Mathur (part-time), J. Gilbert-Tomlinson (part-time).

The objectives of the Wiso Basin project are to produce the outstanding six First Edition 1:250 000 geological maps and accompanying explanatory notes, and to prepare a bulletin outlining the geology of the whole Wiso Basin and including data on drilling and geophysics. Fieldwork was carried out in June and July 1975.

By October 1976 four geological Sheets with explanatory notes (South Lake Woods, Winnecke Creek, Tanami East and Mount Solitaire) has been passed to the editors and the remaining two Sheets and texts (Lander River and Green Swamp Well) were in advanced state of preparation. A short paper is being prepared on the structure of the Lander Trough. The bulletion is scheduled for completion by mid-1977.

Definitions of five new stratigraphic names, and a revised definition for the Hanson River Beds have been submitted to the Territories Stratigraphic Nomenclature Subcommittee for approval before publication.

Seventy carbonate samples from outcrops of all carbonate units throughout the southern part of the basin yielded conodont faunas only from rocks of the Ordovician Hanson River Beds, confirming that sediments of both middle Arenig and late Arenig or early Llanvirnian age are present (E. Druce, BMR, pers. comm., 1976).

Claystone from a locality at lat. 19°26'36"S, long. 133°37'6"E, contains ptychopariid trilobite fragments from which a Middle Cambrian (Templetonian) age, previously unrecorded in the Wiso Basin, has been determined (P. Jell, U. Qld, pers. comm, 1976).

Several refinements have been made to the solid geology map reproduced in the 1975 annual summary (Report 194 p. 2). A Palaeozoic dolomite in the southwest of the basin is now mapped as Middle Cambrian in age, and a large area of no outcrop is now thought to be underlain by sandstone and claystone of the Ordovician Hanson River Beds.

A reinterpretation of a seismic survey across the Lander Trough has shown a sequence which includes the Hanson River Beds thickening southwards and faulted against the Arunta Block. The sequence is at least partly of Palaeozoic age and attains a maximum thickness of 1000 m in the eastern part of the Lander Trough.

CANNING BASIN

by

R.R. Towner

STAFF: R.R. Towner, A.N. Yeates (1/11/75 to 1/6/76), D.L. Gibson, (from 1/7/76), R.W.A. Crowe (GSWA)

The objectives of this project are to re-map the Canning Basin in sufficient detail to enable the preparation of all outstanding 1:250 000 First Edition geological maps and Explanatory Notes and the revision of First Edition maps and notes that are out of print. The project is a joint one with the Geological Survey of Western Australia and the Basin Studies Group, BMR. Field investigation began in 1972 and should be completed in 1977. Following the award of a Public Service Board Scholarship A.N. Yeates commenced sedimentological studies of the Broken Hill area at the University of New England in June. In July D.L. Gibson joined the project after a period of secondment to the Geological Survey of Papua New Guinea.

During 1976, photointerpretation and photocompilation of Sahara, Percival, Wilson, Ural, Ryan, Morris, Tabletop, Runton and Rudall 1:250 000 Sheet areas was completed. Preliminary geological editions of Ryan and Percival were released; those of Wilson, Morris and Runton are well advanced. Preliminary editions of Cornish, Crossland and Mount Bannerman 1:250 000 Sheet areas, mapped in 1973, were also released.

Explanatory notes for Lucas, Cornish, Crossland and Mount Bannerman are with the editors. Draft notes for the south Canning Basin Sheet areas and Noonkanbah were well advanced by the end of October.

Two papers, by Crowe and Towner, "Permian stratigraphic nomenclature of Noonkanbah1:250 000 Sheet area" in which are defined new members of the Grant Formation and the Poole Sandstone, and "The depositional environment of the Nura Nura Member, Poole Sandstone in the Canning Basin" were published in the GSWA Annual Report for 1975.

A paper, by Dickins, Towner and Crowe "A Permian cold water marine fauna in the Grant Formation of the Canning Basin, Western Australia" was submitted for publication in the Yuri A. Orlov Memorial Volume of the Palaeontological Society of India.

A Record (1974/159) by Mary E. White and A.N. Yeates describing plant fossils collected during the 1972-73 field seasons was in press at the end of October.

A report on the 1974 mapping of the Permian of Noonkanbah Sheet area was completed as Record 1976/24. The first draft of a Record by Towner, Crowe and Yeates on the results of the 1975 fieldwork in the South Canning Basin was written.

Field Activities

Between 1 July and 30 September, the party mapped Derby and Mount Anderson 1:250 000 Sheet areas. R.V. Burne gave advice on sedimentary structures and the environmental interpretation of various units and J.M. Dickins spent two weeks collecting Permian fossils.

The mapping was done on 1:80 000 scale airphotos (1967), using Landrovers. The main geological results are:-

(1) The subdivisions of the Grant Formation and Poole Sandstone recognized by Crowe and Towner in Noonkanbah during 1974 were extended into the Mt Wynne and Grant Range areas. However, in the eastern part of the Grant Range, subdivision was not possible owing to complex faulting. The Wye Worry Member of the Grant Formation was found to be much thicker and to contain more sand bodies than in the St George Range in Noonkanbah. The Millajiddee Member appears to be much thinner and is absent in many parts of the Grant Range.

(2) A marked unconformity between the Grant Formation and the basal member of the Poole Sandstone, the Nura Nura Member is well defined in many parts of the Grant Range and Mt Wynne area.

(3) Post-Grant Formation and pre-Poole Sandstone faulting is present in the Grant Range. Preliminary interpretation suggests throws on these faults may be in the order of 500 m.

(4) Wrench faulting occurs in the Grant Range.

(5) The subdivision of the Liveringa Group on lithological grounds alone was difficult in many places owing to poor exposure. However, numerous fossils, particularly in the Dry Corner Syncline and McLarty Syncline areas, enabled successful mapping of the units within the group.

(6) The Myroodah Syncline (Mount Anderson) which on the First Edition Map is shown to consist entirely of Permian Liveringa Group sediments was found to have a core of Erskine Sandstone surrounded by Blina Shale, both of Triassic age.

(7) The Mowla Sandstone was shown to have an interfingering relationship with the underlying Jarlemai Formation and is therefore considered to be Late Jurassic and not Cretaceous in age as originally thought. Previously unrecorded plant fossil localities were found in the Mowla Sandstone.

(8) An interfingering relationship was also mapped between the Jurassic Melligo Quartzite and the Jowlaenga Sandstone at Reeves Hill (Derby).

(9) An exposure of Jurassic Jurgurra Sandstone in Geegully Creek (Mount Anderson) is considered to be an aeolinite, on the evidence of sedimentological structures.

(10) Previously unrecorded bivalves and gastropods were found in the Fraser River area (Derby) in mudstone which is probably equivalent to the Jurassic Jarlemai Formation in the Edgar Ranges (Mount Anderson).

(11) The Jurassic Mudjalla Sandstone consists of at least four different facies including rocks of shallow-water marine and fluviatile origin.

OFFICER BASIN

by

M.J. Jackson

STAFF: M.J. Jackson (part-time)

The main objectives of the Officer Basin project are to understand the geology of the Western Australia part of the Officer Basin and to publish the results in the form of: twenty 1:250 000 geological maps and Explanatory Notes, a bulletin synthesizing the geology of the whole area accompanied by 1:1 000 000 geological and geomorphological maps, and papers on specific aspects of the geology. The project is a joint one with the Geological Survey of Western Australia. Geological mapping was done in 1970 and 1971, and shallow stratigraphic drilling and geophysical work in 1972. Reporting of results started in 1973 and continued throughout 1974 and 1975.

During 1976 Jackson worked only part-time on outstanding Officer Basin commitments. For 8 months he was involved with the organization of the 25th International Geological Congress, which was held in Sydney in August.

In the 4 months available, emphasis was placed on completing the outstanding Explanatory Notes and First Edition maps. At the end of 1975 eighteen of the twenty notes had been written (6 had been issued and 12 were in various stages of editing). During 1976 the notes for the outstanding two Sheet areas (Robert and Waigen) were written and passed on to the editing section. The Explanatory Notes for Browne and Madley were issued during the year, thus leaving twelve sets of notes in various stages of final editing or printing.

Progress was made on the preparation of 1:1 million scale maps to accompany the Bulletin. The geological map was compiled and three cross-sections and the legend were drawn. Compilation of the geomorphology/physiography map was started.

LACHLAN FOLD BELT PROJECT

by

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

The objectives of the Lachlan Fold Belt project are - to assist in the revision of the Canberra 1:250 000 Geological Sheet, to provide basic information for engineering geology investigations, and to obtain a clearer understanding of the

igneous activity and mineralization of the area. The mapping is being carried out in close association with the Engineering Geology Group, BMR and the Geological Survey of New South Wales. The latter has mapped the Braidwood and Michelago 1:100 000 Sheet areas and is co-operating with the Bureau in mapping the Araluen 1:100 000 Sheet area starting in 1977. The Tantangara, Brindabella and Canberra 1:100 000 Sheet areas are being mapped by the Bureau and progress is presented below.

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

Mapping was completed in 1974, preliminary editions of both 1:100 000 sheets are available, and a descriptive record of the Tantangara Sheet area has appeared (Record 1974/176). Most of the past year has been spent preparing an account of the geology of the two Sheet areas for publication, due to be completed early in 1977, and little fieldwork was done. However a five-day field excursion was held in February, when fifteen geologists from the NSW Geological Survey, universities, and BMR were shown the geology of the two Sheet areas.

Much of the emphasis during the year has been on petrographic study of the various igneous units of the area, particularly volcanic rocks, and major differences between units previously thought to be closely related have been noted. The importance of this work is well demonstrated in the Ordovician basic volcanics of the Kiandra area, where it can be shown that two suites of volcanics are present, one with island-arc tholeiitic affinities, and the other with high-K calcalkaline affinities. Subsequent geochemical work during the year has confirmed the petrographic conclusions. A puzzling aspect of these Ordovician basic volcanics is that the tholeiitic volcanics are younger than the high-K calcalkaline rocks, the reverse of the currently-held concept of island-arc development. Further geochemical and Sr isotopic work is in progress.

Several hundred thin-sections of the Silurian acid volcanics of the region have been examined. They show the widespread alteration of mineral phases that has occurred, particularly albitization of plagioclase and chloritization of ferromagnesium minerals. Detailed petrography of unaltered or only partly altered rocks has enabled the original mineral phases in completely altered rocks to be identified in many cases. Five ferromagnesium minerals dominate the suite: biotite, cordierite, hypersthene, garnet and hornblende, each having its own distinctive style of alteration and crystal outline, and different assemblages are characteristic of each volcanic unit. For instance in the Cotter area, west of Canberra, the Paddys River Volcanics contain the assemblage quartz, albite, biotite $\pm$ cordierite $\pm$ garnet; the Walker Volcanics quartz, albite, biotite, garnet, $\pm$ hornblende, and the Willow Bridge Tuff quartz,

labradorite (strongly zoned), sanidine, biotite, hypersthene, ± cordierite. This last unit, the Willow Bridge Tuff, is particularly distinctive, and can be shown to extend with identical lithology from Boambolo in the north to the Woden Valley and Tuggeranong, south of Canberra, a distance of about 45 km. It is also unusual for containing the rare earth mineral allanite, which is virtually unrecorded from volcanic rocks.

During a field re-examination of the Devonian Hatchery Creek Conglomerate during the year a layer containing fossil fish and plants was located, and an extensive fauna and flora collected. This is the first to be found in the Conglomerate, and contains several species, all of which are apparently undescribed; it appears likely that the fauna is of Middle Devonian age. Concurrent studies of the sedimentology of the Conglomerate has shown that it is composed of fining-upward cycles which commence with a basal conglomerate having scoured contacts with the preceeding cycle, and end in a soil horizon containing root-casts. It is thought that the Hatchery Creek Conglomerate was deposited by braided streams on an alluvial fan.

Canberra Sheet area (R.S. Abell)

An initial evaluation of the geology of the Sheet area was made by compiling a map at a scale of 1:25 000, mainly from BMR Reports and Records, university theses, and company reports. After compilation it was found that only about 10% of the Sheet area was without some detailed geological information. The compilation map will be used as a base for planning field work and presentation of field data; the map produced at 1:25 000 will be reduced to a final scale of 1:100 000. Field work commenced in April and to date an area bounded to the east by the Lake George escarpment and to the west by the Queanbeyan-Gundaroo road has been mapped, about 20% of the Sheet area.

ORDOVICIAN SEDIMENTS

Most of the area is underlain by Ordovician distal flysch composed of well-bedded arenite and argillite. Sedimentary structures (mainly graded bedding) show that in some places the sediments are downward-facing, suggestive of an early F_1 fold phase (Stauffer & Rickard, 1966). Most fold structures that can be mapped relate to an F_2 fold phase (Bowning Orogeny) which consists of open asymmetrical flexural style folds with shallow plunges to north or south; small-scale pucker folds in laminated shale and siltstone reflect the trend of major N-S fold axes. A cleavage striking consistently NNE is axial planar to F_2 folds and sub-parallels the strike of the bedding. Late-phase kink folds with steeply dipping axial plane cleavage are suggested from the folding of an F_2 cleavage and foliation. A shallow crenulation cleavage seems to be locally associated with major fault zones.

SILURIAN SEDIMENTS

Outcropping along the Lake George Range is a sequence of westerly-dipping dark green to black shale, possibly tuffaceous siltstone, sandstone and rhyolitic lava of Late Silurian age. These sediments probably have a faulted contact with the Ordovician to the west and represent a northerly extension of the Carwoola Beds and Captains Flat Formation along the western margin of the Captains Flat graben. Mapping has yet to establish how much farther these formations might extend along the Lake George escarpment.

IGNEOUS ACTIVITY

Exposed along the Lake George escarpment where it borders the lake are numerous N-S trending bodies of quartz-feldspar porphyry. They are clearly mappable field units with sharp cross-cutting contacts of up to 10^{0} with the surrounding sediments. Although individual bodies can only be traced over short distances they tend to decrease in a westerly direction from the Lake George fault zone, but traced towards this zone the porphyries become progressively foliated and may be sheared enough to be termed mylonites. Similar porphyries exposed in the Molonglo River catchment are also intrusive. They have ubiquitous trends and a foliation parallel to the cleavage in surrounding Ordovician sediments suggests they were intruded during the period of F_2 deformation. It appears that these porphyries are probably offshoots of a more extensive granite body at depth which acted as a feeder for dykes and sills that gave rise to an extensive Upper Silurian volcanic cover that has since been eroded from higher ground. At Geary's Gap there are porphyries which have a gradational contact with the sediments, suggesting they are interbedded in the sequence. If this is the case then it is possible that they represent evidence for local acid volcanicity in the Ordovician.

A number of granitoid bodies have been mapped which are elongated in a N-S direction parallel to the regional structural trend; the largest body is the Bywong Granite east of Sutton. This granite has developed a contact aureole in the Ordovician sediments, causing local hardening and the formation of spotted hornfels, the spots developing more prominently in the argillaceous bands. A local swing in strike of the bedding from N-S to E-W and an absence of cleavage in the thermally metamorphosed sediments suggests the Bywong Granite exerted some structural control during the F_2 fold phase.

Basic rocks consisting of gabbros and dolerites outcrop along the Lake George Range where they appear to intrude Upper Silurian sediments. The co-existence of basic rocks with major fault zones suggests that crustal fracturing to great depths accompanied the formation of the horst-graben systems in the area.

DETAILED STUDIES

SOUTHWEST QUEENSLAND GEOMORPHOLOGY

by

B.R. Senior

The objectives of the southwest Queensland geomorphology study were to outline the nature of chemical weathering processes, landform development and neotectonics in southwest Queensland. This was achieved through geological mapping, shallow stratigraphic drilling and interpretation of RC9 aerial photography and Landsat-1 imagery. Parent rocks and weathered profiles identified in the field were studied by describing and sampling reference (type) sections. Samples from these reference sections were analysed using clay mineral, geochemical and petrographic techniques.

Research was orientated to establish basic criteria for recognition and map portrayal of parent and weathered rocks through a study of the geology, landforms and tectonic framework of a selected 'type' area. A preliminary special map of this area at 1:250 000 scale (Geology and Geomorphology of the Haddon Corner area) was produced during the year. This map demonstrates the potential contribution of physiographic analysis to geological mapping in an area extensively mantled by weathered profiles and surficial sediments.

Four distinct profiles, which were informally named, were defined in southwest Queensland. Each consists of a sequence of weathered layers grading down from the surface to unweathered rock. These profiles are widespread, though in places they are incompletely developed because there was interaction between surfaces of weathering and surfaces of accumulation. The time relationships between weathering and depositional events are illustrated diagrammatically in Fig. S3.

Both kaolinitic and siliceous profiles are widespread in the region. Kaolinitic profiles are up to 100 m thick and have developed in quartz-deficient sedimentary rocks of the Cretaceous Rolling Downs Group. Siliceous profiles are thinner (average 3 m) and have formed within quartzose sedimentary rocks of the Glendower Formation. The preservation of the kaolinitic profiles was aided by burial beneath Lower Tertiary fluviatile sediments.

Three of the profiles (Morney and Canaway profiles and Curalle silcrete profile) relate to the weathered landsurface below which they formed. Some silcretes, however, formed within sequences of unweathered quartzose sediment. These occurrences lie within the limbs of folds and relate to geochemical and hydrodynamic factors which led to silica precipitation within beds of suitable porosity and permeability.

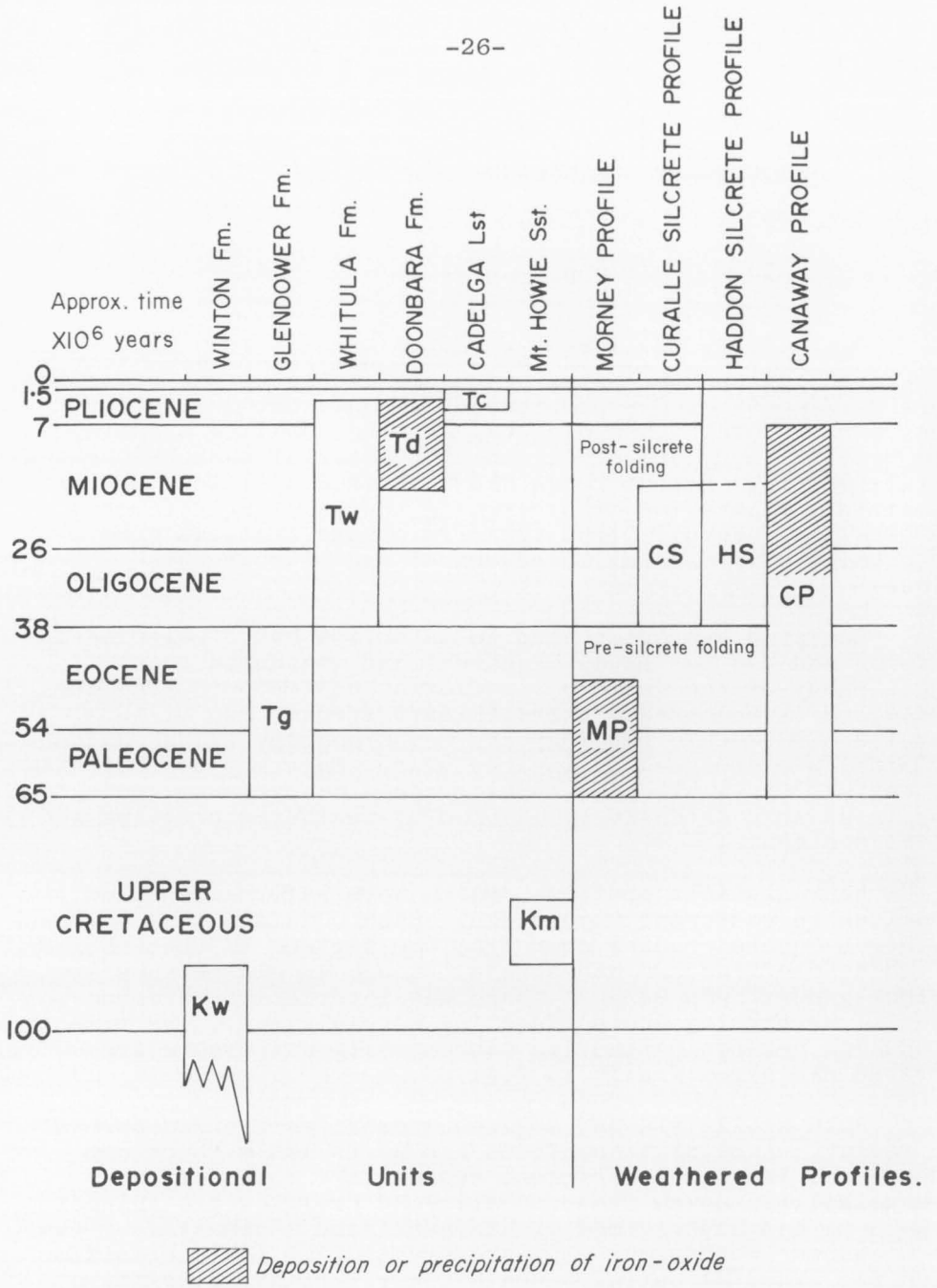

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Fig. S3. A comparison of time ranges of depositional units and weathered profiles in southwest Queensland and adjacent areas of South Australia.

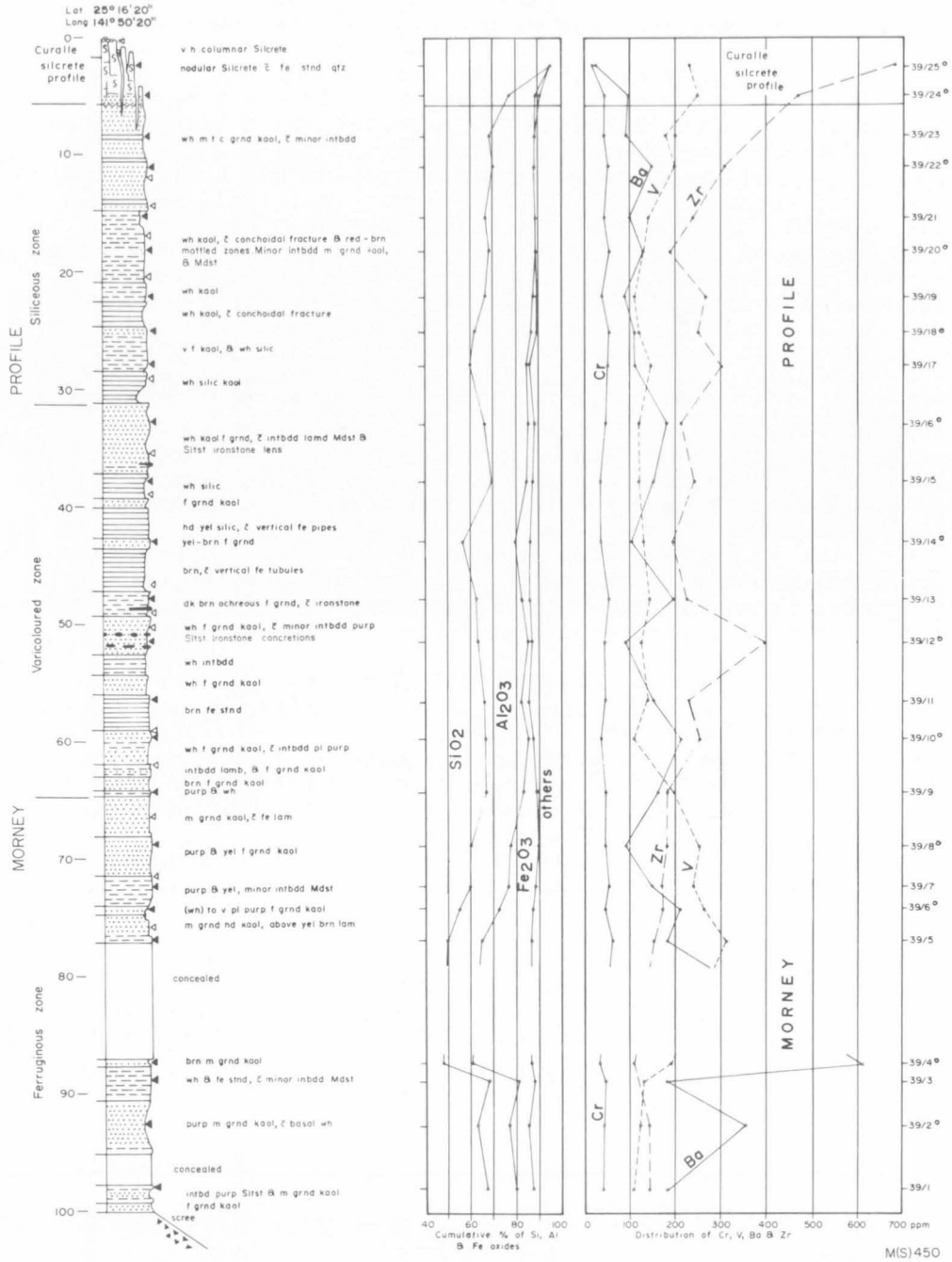


Fig. S4. Reference section of the Morney profile showing the distribution of major oxides and selected trace elements.

Quantitative geochemical and clay mineralogical data substantiated the field identification of distinct weathered profiles. Observed zonation within profiles was confirmed by these analyses. In the example provided (Fig. S4), the reference section of the Morney profile, the variation of silica, alumina iron-oxides and selected trace elements is in close agreement with the observed ferruginous, varicoloured and siliceous zones.

No dating of the weathered profiles has been attempted in the past because of the lack of organic material, and igneous rocks suitable for isotopic age determination. Estimates of the age of weathered profiles have been based on geomorphic evidence derived from identification and extrapolation of ancient land surfaces. A study of the remanent magnetic properties of the ferruginous components of weathered profiles was undertaken in conjunction with Dr M. Idnurm (Geophysical Branch). Timing of weathering events relies on a comparison of remanent magnetic directions with the established polar wander curve. The results established two periods of weathering in southwest Queensland. Kaolinization and formation of the basal ferruginous zone in the Morney profile occurred during the Maastrichtian to early Eocene. Widespread ferruginous crusting, which formed the Canaway profile, occurred in the late Oligocene and ?Miocene. This latter event is probably linked with the movement of siliceous groundwater and the formation of precious opal below the ferruginous crust of this profile, and widespread silicification in adjacent areas, within fluviatile quartzose sediments.

The use of palaeomagnetism in the dating of weathering processes in southwest Queensland could be extended to establish a continent-wide correlation between weathered profiles of contrasting morphology. This technique could be applied to the timing of the formation of weathered rocks of economic significance (bauxite, precious opal, lateritic nickel, gossans etc).

Reporting on this project in the form of a doctorate thesis was completed at the University of New South Wales.

Publication of the results of this project is under review. However, it seems likely that a series of publications will be prepared outlining various aspects of the study. The first of these, concerned with the palaeomagnetic technique, is in an advanced stage of preparation and publication is planned in early 1977.

MAGNESITE AT GOSSES BLUFF, N.T.

by

A.T. Wells

The objective of the project is to report on magnesite in calcrete at Gosses Bluff, NT, discovered during regional mapping of the area.

Late Cainozoic calcrete underlies an area of about 15 km^2 around Gosses Bluff and small nodules and tabular bodies of practically pure microcrystalline magnesite up to a few centimetres across constitute somewhat less than 1% of the outcrop. The bedrock in the area of calcrete is impact breccia of the Gosses Bluff Structure. The history of the deposit involved at least two episodes of precipitation from groundwaters of differing chemistry separated by a period of desiccation and perhaps subaerial exposure.

In the first episode the groundwaters precipitated magnesium carbonate and the second episode led to deposition of calcite and partial replacement of magnesite nodules, and finally the deposition of calcrete.

Magnesite has rarely been reported in Australian calcretes; information on its origin at Gosses Bluff may indicate where richer, possibly economic deposits might have accumulated elsewhere on the continent.

A paper summarising the results of the investigation was prepared for inclusion in the BMR Journal.

RINGWOOD EVAPORITE STUDY, AMADEUS BASIN, NT

by

A.J. Stewart

A.J. Stewart (Metalliferous Section) and D.Z. and J.H. Oehler (Baas Becking Laboratory) discovered microfossils in chert associated with bituminous dolomite in the Ringwood Evaporite deposit in the Gillen Member of the Adelaidean Bitter Springs Formation of the Amadeus Basin. Similar fossils are well known in the overlying Loves Creek Member of the same formation, but have not previously been found in the Gillen Member. The evaporite core was sampled and thin-sectioned preparatory to further study of the fossils.

Report 186 'Petrographic and geochemical study of the Ringwood Evaporite deposit, N.T.' by A.J. Stewart is with the Editors.

HYDROGEOLOGICAL STUDIES

GREAT ARTESIAN BASIN

by

M.A. Habermehl and G.E. Seidel

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

The aim of the Great Artesian Basin project is to study the hydrogeology of the basin, and to produce and apply a mathematical computer-based model which simulates the groundwater hydrodynamics. By simulating proposed exploitation schemes and predicting hydraulic changes, the model could assist in the management of the groundwater resources.

Over the period from 1972 to 1974, and with assistance from staff provided by BRGM (Australia) until 1975, geological and hydrological data from BMR, State Geological Surveys and Water Authorities were compiled and transcribed, and most hydrological data computer processed and stored. Analysis of the hydrogeological information resulted in the definition of a prototype of the Great Artesian Basin, consisting of two confined aquifers (Jurassic and Cretaceous sandstones), two confining beds (Cretaceous mudstone and siltstone), and a near-surface water-table, which approximates a constant head boundary compared with the changing heads of the confined aquifers. The prototype forms the link between the real basin configuration and the model. For computations the prototype is defined by a series of numerical maps of potentiometric surfaces, well discharges, aquifer geometry and hydraulic parameters which were derived from the data recorded in the GAB-ADP system.

The digital computer model used is based on finite difference approximations of the Hantush approach for leaky aquifers. Model calibration, that is the process of adjusting model parameters until the model correctly reproduces the available historical data, was applied to the original GABSIM model during 1974 and early 1975. A 'direct' method developed during 1975 resulted in the successful calibration of the GABSIM model for the 1880 (steady-state) conditions; however the non-steady-state version of the GABSIM model proved to be unworkable applied to the GAB. A new model program system, GABHYD, was then developed during the second half of 1975.

During 1976:

- The GABHYD model program system was expanded.
- A series of programs was developed for a complete 'direct' calibration.
- The new programs were applied to a representative section of the GAB and application of the programs to the whole basin was commenced.
- Documentation commenced of the hydrogeology of the GAB and of the GABHYD model and calibration programs.

GABHYD program system expansion

The prediction version of the model, which is used to simulate unknown conditions commencing with known conditions, was supplemented by a historic model version. The historic version is used to calculate potentials in the basin in accordance with the hydraulic parameters and recorded well discharge values but to replace the calculated potentials with recorded ones whenever these are available. The purpose of this program is to specify values on nodes, where records are not available, in accordance with the basin hydraulics as expressed by the model hydraulic parameters rather than by an arbitrary linear interpolation. Such intermediate data are necessary for any model calibration.

Direct calibration

A set of calibration and data manipulation programs was developed, which allow the adjustment of the model hydraulic parameters in a systematic step by step procedure until the model is capable of reproducing the historical recorded data of potentials and discharges. The hydraulic parameters included in this procedure are all interior transmissivities and storage coefficients. Transmissivities on permeable boundaries and vertical permeabilities are boundary conditions and hence not included in the calibration changes.

Trial application to section of GAB

To verify the correct operation of model and calibration programs at a moderate computing cost, a representative section of the basin was selected and isolated by the insertion of hypothetical impermeable boundaries. The small independent basin thus generated was then calibrated using the above mentioned programs. This was followed by a trial prediction run of the model over a period of five years starting from known conditions. The results were compared with the data which were recorded for the prediction period but had not been supplied to the model. The accuracy of potentials and discharge predictions was good throughout with a standard error of 5.6% (average error 3.4%) for the values of discharge and pressure above ground (net potential).

The trials at the same time seemed to develop a systematic procedure for applying the calibration programs to the whole basin. This overall calibration of the model has reached an advanced stage.

Documentation

Documentation of the calibration programs commenced and several sections were completed. The remaining sections are to be added after the model calibration has been verified.

Writing continued on the report Hydrogeology of the Great Artesian Basin, and dealt with data collection and preparation, previous investigations, geology and groundwater hydrology.

Additions and alterations were carried out to the figures, maps and cross-sections accompanying the GAB progress report 1972-1974, which describes the preparation of the input data for the model. Checking, correcting and editing of this report and the explanatory note on the GABSIM digital model package was performed before submission for printing.

A short field trip was made to the natural discharge area in the southwestern part of the Great Artesian Basin in South Australia during September 1976. Mound springs in the Dalhousie and Oodnadatta-Marree area, exposed aquifers and confining beds, flowing artesian water-wells and the flooded Lake Eyre were examined. During part of the trip, officers of the Australian Atomic Energy Commission sampled water from moundsprings, wells and Lake Eyre for isotope dating analyses.

WIRELINE LOGGING OF WATERBORES IN THE GREAT ARTESIAN BASIN

by

M.A. Habermehl

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

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

Almost all existing waterwells in the basin are lined with metal casing, and this restricts the borehole geophysics to nuclear logs. Generally, logs obtained consist of natural gamma-ray, neutron, temperature, differential temperature and casing collar locator logs. In uncased holes, or if sufficient open hole occurs, electric and caliper logs are also run. Some flowing artesian wells are logged with a flow-meter.

Table S1. Wireline logging of waterwells in the Great Artesian Basin results obtained in Queensland, 1975

Depth in feet

All logs at scale 1 inch to 100 ft and 1 inch to 20 ft

1:250 000 map sheet		Wells logged	Total depths of wells	Total intervals logged	Logs obtained						Minimum total depth	Maximum total depth	Minimum interval logged	Maximum interval logged
					G	N	T	F	C	CCL				
LONGREACH	SF55-13	4	8625	8449	4	4	4	4	4	4	1531	2770	1530	2638
BLACKALL	SG55-1	2	9498	5860	2	2	2	-	-	2	4205	5293	570	5290
TAMBO	SG55-2	6	13189	11414	6	6	6	5	6	6	1464	2814	1334	2570
AUGATHELLA	SG55-6	16	19928	17973	16	16	16	2	2	16	200	4013	187	3538
CHARLEVILLE	SG55-10	11	19286	18416	11	11	11	5	5	11	1040	3500	1057	3506
TOOMPINE	SG55-13	2	3655	3630	2	2	2	2	2	2	1820	1835	1814	1816
WYANDRA	SG55-14	5	9312	8938	5	5	5	4	4	5	1693	2050	1541	2003
EULO	SH55-1	7	5678	5387	7	7	7	3	6	7	455	1406	433	1266
CUNNAMULLA	SH55-2	3	5281	5198	3	3	3	3	3	3	1521	1916	1502	1910
	TOTAL	56	94452 (28788.7 m)	85265 (25988.7 m)	56	56	56	28	32	56				

G - natural gamma-ray, N - neutron-gamma, T - temperature and differential temperature, F - flowmeter, C - caliper, CCL - casing collar locator

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

The Geophysical Branch of BMR logged, during September to November 1975, 56 waterwells in the central and southern Queensland part of the Great Artesian Basin. These wells had earlier been sampled by the Australian Atomic Energy Commission for isotope dating analyses (see Geol. Br. Summary of Activities 1975). The wells are in the region around Charleville, and tap aquifers in Jurassic and Lower Cretaceous rocks. Groundwater movement in these aquifers is from the eastern recharge areas towards W, SW and SSW directions. The wells logged by BMR have a total depth of 28788 m (94452 ft), and the total depth interval logged amounted to 25988 m (85265 ft) (Table S1).

Basic well data, types of logs run, log data, stratigraphical and hydrological information obtained and the results of chemical analysis of water samples from wells logged were collected, checked and compiled. These data concern about 1200 waterwells, including artesian and subartesian waterwells, and some converted petroleum exploration wells in Queensland, New South Wales and the Northern Territory, which were logged by BMR and its contractors since 1960.

A data transcription manual and data transfer sheets were prepared to transcribe the above mentioned well and log data, and chemical analysis results. Data recorded on the fixed format coding sheets will be transferred to punch cards and subsequently incorporated into the GAB-ADP system, after which computer retrieval and processing becomes possible.

Transcription of the basic well and log information commenced early in 1976 and was completed in October 1976.

PHOTOGEOLOGY AND REMOTE SENSING

by

C. Maffi and C.J. Simpson

STAFF: C. Maffi; C.J. Simpson; R. Scott (part-time from 19.1 to 11.2)

BMR MAPPING PROJECTS

To assist field personnel in the planning and execution of their work, the following photointerpretation projects were carried out:

Lawn Hill Project. Interpretation of colour air photographs of the Bowthorn and Lawn Hill 1:100 000 Sheet areas. About 75% of the area was covered. The Lawn Hill interpretation was compiled on photo-mosaics.

Pine Creek Geosyncline Project. Interpretation of colour air photographs of the northern three-quarters of the Mundogie 1:100 000 Sheet area. The members of the Group attended the meetings of the Pine Creek Geosyncline Discussion Group, and presented suggestions on a remote sensing survey of the area. Such a study should: a) determine what - if any - surface parameters are affected by U mineralization; if a) is successful, then: b) determine which wavelength band(s) is (are) best suited to detect those parameters; c) plan the survey accordingly. Literature reports some successes in the detection of U mineralization by use of thermal IR imagery and of ratioed and stretched Landsat data.

Engineering Projects. Detection of areas of structural weakness and determination of slope stability by photointerpretation of a proposed damsite in Fiji.

REMOTE SENSING

Landsat. The geological information content of a second generation Landsat image of the Marraba area, Qld was investigated. The negative from which the image was printed had been prepared by CSIRO Mineral Physics Laboratories from NASA computer-compatible tapes. The study showed that Landsat second generation images contain more geological information than images normally obtained from NASA (5th generation). Nevertheless, considering the cost (in Nov. 75 for Government users computing cost was $400 per spectral band), the use of such images in an area of complex geology already covered by 1:100 000 geological maps is probably not worthwhile.

The Landsat coverage of Irian Jaya was ordered from NASA, received and indexed. The 1:1 000 000 scale paper prints were delivered to the field party; the 70 mm positive transparencies for use with the multispectral viewer were stored in the Group.

Skylab. The final report on the project, illustrated at NASA's request with colour photographs instead of panchromatic as in the draft, was dispatched to NASA in December and accepted in February. The work on the limited amount of Skylab photography of Australia suggests that small-scale aerial photography (1:100 000 and smaller) would be a valuable aid in natural resources mapping.

The distribution of linear features interpreted from Skylab high resolution photographs of the Snowy Mountains area

was analysed by computer. The purpose was to investigate the reason why the distribution of linear features from high resolution photographs did not appear to be related to geology, while that of linear features from low resolution photographs did. The computer analysis failed to solve the problem. A review of the geological aspects of the Skylab study was prepared for publication in the BMR Journal.

Normanton Flood Project. A paper was prepared in conjunction with H.F. Doutch for the BMR Journal on the 1974 flooding of the Gulf Country, as assessed by interpretation of photographs taken from a light aircraft with small-format, hand-held cameras.

The objectives of the aerial survey were twofold. Firstly to examine flood phenomena which may relate to an understanding of past and present geomorphological development and lithostratigraphy of the Upper Cainozoic fluviatile plains. Secondly to observe the effects of high rainfall and flooding, that may influence the identification and interpretation of features observed on Landsat satellite imagery of flooded or wet terrain, and their corresponding appearance on "dry" season satellite imagery and air photography.

Landsat flood imagery of the Carpentaria Gulf plains contains information on water movement and its geomorphic implications that cannot be interpreted from dry season aerial photographs, or topographic maps. It is possible to delineate areas of clear water and subdivide waters with different concentrations of sediment load. Neither the colour nor colour infrared photographs taken during aerial observations proved useful in recording the existence or distribution of clear stormwater unless sun reflection was present.

The data from aerial observation combined with available Landsat imagery over the Gulf region allow the establishment of interpretation keys to assist assessment of any flood imagery acquired by future Landsat satellites.

CSIRO Multispectral Photography. The assessment was commenced of the usefulness for geological applications of the multispectral photography flown in 1972 by RAAF for CSIRO. An area of about 600 km^2 in the Marraba (Mt Isa region) 1:100 000 Sheet area was selected for the study.

OVERSEA VISIT

Maffi attended a UN/FAO Seminar on Remote Sensing Applications, Jakarta, 19-28 November, under the sponsorship of ADAA. The purpose of the meeting was to exchange information on operational remote sensing techniques and to study their applications to tropical environments. Maffi delivered a lecture and held a workshop on the applications of thermal infrared and side-looking radar imagery to geological mapping. He also read a paper prepared by DNM personnel on cartography from small scale imagery.

The seminar recognized that satellite imagery is the cheapest and most readily available source of land information for poorly mapped developing countries, and recommended, among other things, that: direct receiving facilities for satellite data should be established in the ESCAP region as soon as possible; assistance and training in remote sensing applications should be provided by advanced to developing countries; research should be intensified in the development of sensors more suitable than the existing ones to the tropical environment, in the development of remote sensing applications in various disciplines, and in remote sensing data processing and analysis. The seminar also recognized the importance for geology and geomorphology of stereoscopy in satellite imagery.

EXTERNAL PROJECT

by W.J. Perry

The Department of Science, through the interdepartmental committee ACERTS, sought information for a submission to Cabinet recommending the establishment of Landsat receiving and processing facilities. BMR was asked to prepare a document summarizing the geological applications of Landsat data, and a paper was compiled by W.J. Perry, the Bureau representative on the ACERTS committee, based on the results of Australian ERTS-1 program, overseas experience and information supplied by State Geological Surveys. The conclusions are as follows: "the applications for which Landsat data have value at present are: 1. Regional geological mapping, as a basis for mineral exploration (including petroleum); as a supplement to aerial photography Landsat imagery provides the broad framework, in many places permits the recognition of previously unknown linear features and the extension of previously known ones; in certain areas it permits broad correlation of rock types. Hence Landsat can improve geoscientists' understanding of the broad geological features of an area, and leads to new ideas about its geological development, with the possibility of suggesting new hypotheses of mineralization. 2. The analysis of linear features, which may aid in the location of targets for hydrocarbon and groundwater exploration. 3. Environment monitoring, including the use of data collection platforms for relaying data from remotely sited instruments, for example, stream gauges. 4. Terrain analysis."

It was also concluded that in the longer term, regional geological mapping will be assisted by computer-aided manipulation of digital multispectral scanner data, for example band-ratioing for the discrimination of surface materials in well-exposed terrain.

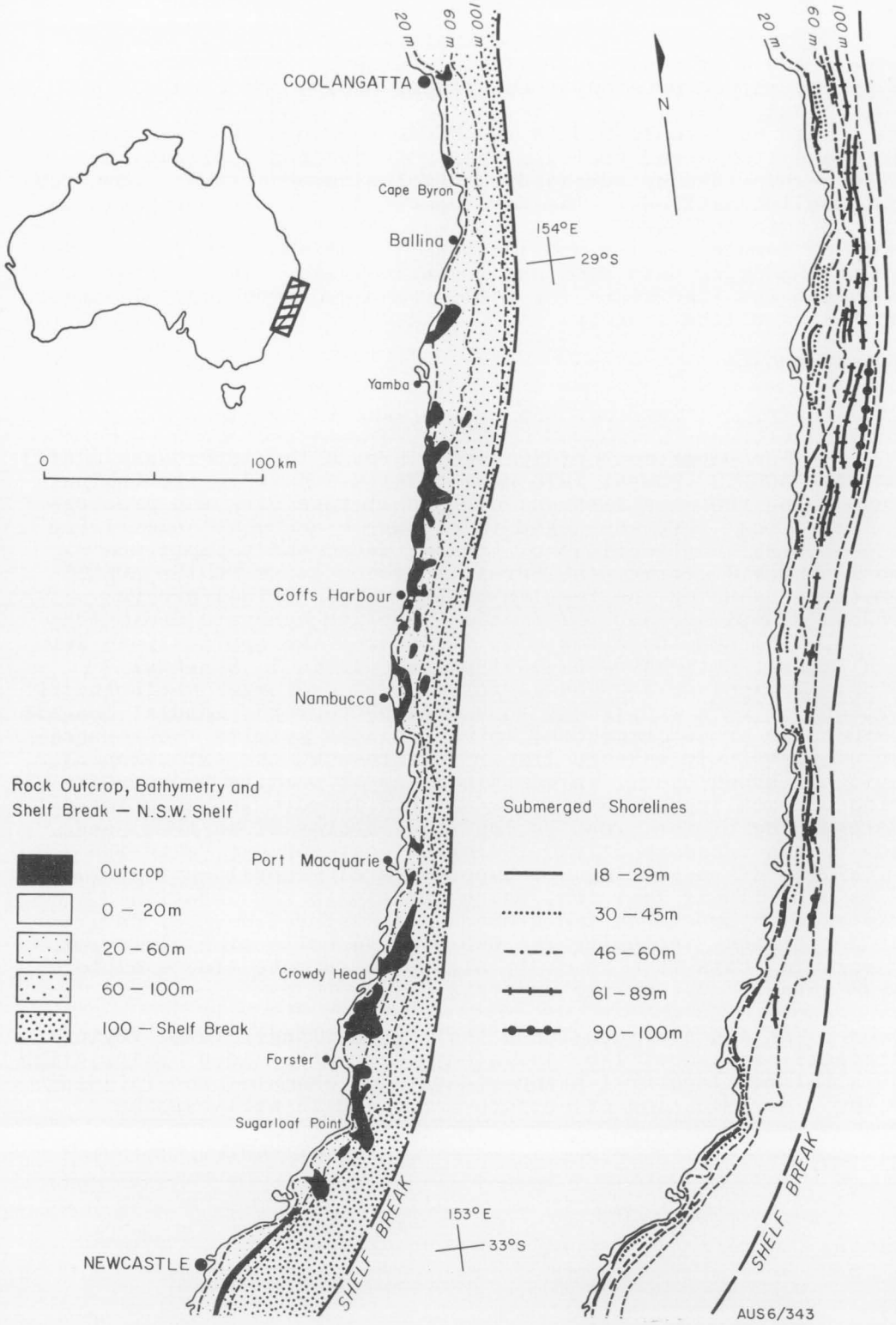


Fig. S5. Submerged shore-lines and bathymetry, northern NSW Continental Shelf.

MARINE GEOLOGY AND COASTAL STUDIES

OFFSHORE HEAVY MINERAL SANDS

by

H.A. Jones and P.J. Davies

A review of east coast offshore heavy-mineral prospects was carried out during 1976 using available company data, data from BMR's regional reconnaissance surveys in 1970 and 1972, additional seismic profiles collected by BMR in 1974, and detailed bathymetric surveys by the RAN and the Division of National Mapping.

Substantial, but very low grade resources of heavy mineral sands were indicated by Planet Metals Ltd drilling in the 1960s offshore from the beach mining areas of the New South Wales and southern Queensland coasts, but no potentially mineable deposit was outlined, and the drilling yielded no obvious explanation of the distribution of the heavy mineral concentrations discovered which might aid further exploration. Enough work was done to greatly downgrade the prospects of finding large, rich, heavy-mineral concentrations in the inshore zone.

Interpretation of bathymetric and seismic profiles by BMR has enabled possible submerged strandlines to be plotted as well as bedrock outcrop and sediment thickness (Fig. S5). Two sedimentary sequences, commonly separated by a disconformity, have been identified over much of the area. Relative enrichment with heavy minerals (1.4% rutile-plus-zircon) was recorded in one of the bores drilled by Planet Metals Ltd close to the base of the upper sequence in the outer part of the present-day paralic zone sediment wedge near Forster, NSW. Areas where this horizon occurs close to the sea floor in moderate water depths merit further investigation, particularly when associated with strandline morphology.

Two theoretical factors weigh against the existence of large accessible offshore heavy mineral sand accumulations. First, there is evidence to suggest that during a marine transgression the body of sand in the beach zone, together with any mineral concentrations it may contain, will tend to migrate landwards with the advancing shore. Only a minor proportion of this sand body, and an even smaller proportion of the heavy fraction, is redistributed during a subsequent regression. The end result of a series of sea-level fluctuations is therefore the build-up of massive coastal sand deposits in the region of the highest sea level which will contain the bulk of the beach zone sand and associated heavy minerals formerly distributed over the shelf. These are the rich and extensive onshore east coast beach sand deposits now being exploited on a large scale.

The second unfavourable factor concerns the depth of submerged shorelines. During much of the Pleistocene, sea level fluctuated between 60 and 100 m below that of the present day; thus even if heavy mineral seams in these ancient strandlines escaped reworking as sea level rose, they would be beyond the reach of present-day dredging techniques.

However, despite the above comments, the fact remains that we do not know all the factors controlling the distribution of heavy minerals in sediments affected by repeated transgressions and regressions of the sea. Some fossil strandlines occur in moderate water depths, there are adequate thicknesses of sediment in many places, and there is some stratigraphic information to help guide exploration. Pioneering company exploration has indicated some enrichment in the near-shore zone: further work there and in deeper water may reveal economic deposits.

CENTRAL EAST AUSTRALIAN SHELF HEAVY MINERALS

by

J. Smart

The objective of the study was to gain an understanding of the nature and distribution of the heavy minerals in the northern New South Wales southern Queensland continental shelf. This will complement studies of shelf morphology and other factors involved in the concentration of heavy minerals by H.A. Jones and P.J. Davies and will assist in the selection of areas for future investigation by geophysics and drilling.

The study was based on sea-bed dredge samples collected on BMR cruises in 1970 and 1972. Interpretation of the results is constrained by the wide spacing of sample points (average about 30 km) and the small vertical interval represented by the samples.

Distribution of total heavy minerals showed that while the overall content was very low (generally less than 0.1%) a few areas have much higher values (0.5 to 1.0%, exceptionally 2.0%). Contents of zircon plus rutile range from zero to 14 percent of the heavy minerals, averaging 3 to 5 percent. Magnetite-ilmenite commonly forms 30 to 40 percent of the heavy fraction. Other heavy minerals include amphiboles, alumino-silicates, epidote, garnet, and tourmaline.

Comparison with the shelf morphology work of Jones (Records 1973/46, 1973/123 and 1974/51) show that relatively high values of heavy minerals occur in the vicinity of features inter-

preted as old shore lines in two areas; east-southeast of Caloundra, where total heavy minerals are up to 0.7 percent and zircon plus rutile up to 15 percent of total heavy minerals; and east of Double Island Point where total heavy minerals are 2 percent and zircon plus rutile 14 percent of total heavy minerals. Water depths in both areas are 50 to 60 m. Such areas may warrant further investigation. However, none of the other areas of relatively high heavy mineral content are near old shorelines.

Experiments were carried out with the scanning electron microscope to develop a method of rapid identification which would reduce the need for point counting. By scanning for six elements it was possible to obtain conclusive identification of the economic heavy minerals and a broad grouping of the others. The investigation has still to be completed but the method shows promise and by the addition of computer facilities the SEM could provide a rapid objective semi-automatic procedure for analysing heavy mineral assemblages where the principal interest was economic.

BIBLIOGRAPHIC STUDIES OF THE GEOLOGY OF AUSTRALIAN HEAVY MINERAL SAND DEPOSITS

by

J. Gardiner

This bibliographic study of Quaternary coastal deposits and heavy-minerals has progressed to a stage where all known deposits along the coastline of Australia have been recorded. The two aims of the project (1) to produce an A.D.P. based bibliography of relevant published and unpublished documents and (2) a series of maps at a scale of 1:2 500 000 portraying factors fundamental to the accumulation of heavy-minerals along the Australian coastline have been completed.

Over 900 published and unpublished references have been collected as a result of visits to the various state Geological Surveys and from bibliographies supplied by the Western Australian and Northern Territory Geological Surveys and Dr. B. Thom of the Australian National University. The bibliography is now being organised into report form.

During 1976 two records on heavy-mineral deposits along the southern (BMR Record 1976/42) and western coasts of Australia (BMR Record, in prep.) were written. The record synthesizing all information on heavy-minerals along the southern coastline, concludes that (i) all heavy-mineral deposits are found within Holocene coastal deposits, (ii) heavy-minerals are mainly found

on present-day beaches or within beach ridges, (iii) the largest heavy-mineral accumulations are found at the junction of truncated beach ridge systems, (iv) a variety of rock types contribute to the heavy-mineral deposits, (vi) and heavy-mineral deposits do not seem to be present in predominantly calcareous beaches or beaches with calcareous sediments in the coastal plain. The study of heavy-minerals in Western Australia has shown that there are many differences between western and southern heavy-mineral deposits but similarities exist between western and east coast deposits. For example (a) large heavy-mineral deposits in Western Australia occur in coastal deposits dating from the Tertiary to the present and this is similar to the situation on the east coast, (b) zeta-form bays are associated with many of the large deposits, in Western Australia, and on the eastern coast; and (c) the origin of the heavy-mineral at Geographe Bay, along the Gingin Scarp and in the Augusta area, Western Australia, is the Mesozoic sandstone as in the case of the east coast where large heavy-mineral concentrations are adjacent to the Mesozoic rocks in the Sydney and Clarence - Moreton Basins.

Future plans include (1) the construction of maps showing the distribution of heavy-mineral sands and factors affecting their distribution in the Northern Territory and (2) a report noting similarities and differences between the major heavy-mineral deposits in Australia.

COASTAL STUDIES SOUTHEASTERN SOUTH AUSTRALIA

by

J.B. Colwell

Studies of the stratigraphy and sedimentology of the later Cainozoic sediments of southeastern South Australia continued in association with the South Australian Department of Mines, Flinders University and as of June 1976, the Australian National University. The study was undertaken primarily to obtain detailed stratigraphic information on the regressive Quaternary coastal sequence with a view to establishing the nature of Pleistocene sea-level changes in the region. Initial interpretation of the information obtained from BMR drilling undertaken in 1974 and 1975 suggests that there have been at least 20 major high sea-level stands during the last 700 000 years.

Detailed investigation of the mineralogy of the sediments using X-ray diffraction has commenced. As well as establishing variations through the sequence the work aims to identify calcareous muds suitable for uranium-series dating. Petrographic examination of the sediments has been undertaken.

An examination of the nature, abundance and provenance of heavy minerals occurring in the sediments was undertaken. Some interest in the heavy mineral potential of the area has been shown by mining companies in recent years. Material for this study came principally from the Bureau's stratigraphic drilling between Robe and Naracoorte, and west of Bordertown. Concentrations of heavy mineral in the several hundred samples examined are generally low, rarely exceeding 0.5 percent and commonly falling below 0.1 percent, partly as a result of the dilution of the terrigenous fraction by large quantities of locally derived biogenic carbonate. The highest concentration recorded (up to 1.2 percent of which approximately 20 percent is rutile plus zircon) occurs in parts of a very shallow marine calcareous sand unit of probable Pliocene age which underlies the Quaternary beach, dune, estuarine and lacustrine deposits throughout much of the region. In general the suite consists of between 25 and 45 percent of combined magnetite and ilmenite, 5 and 20 percent leucoxene, 5 and 25 percent zircon, 5 and 30 percent tourmaline, and up to 10 percent each of amphibole, epidote, rutile and garnet. Andalusite, sillimanite, kyanite and staurolite occur as minor components in many of the assemblages. Sialic igneous, reworked sedimentary, metamorphic and to a very slight extent mafic igneous components appear to be present. Likely specific sources have been identified.

Magnetostratigraphy has been applied to a limited extent to the sequence. This has shown that virtually the entire beach and dune sequence is younger than the Matuyama Reversed Polarity Epoch which commenced 690 000 years BP. Work is continuing to locate the position of the reversal in the sequence.

Colour aerial photography was flown over parts of the region.

CONTINENTAL SHELF - SOUTHEAST AUSTRALIA

by

P.J. Davies

The morphology, structure, sediment distribution and geochemistry of the shelf between Sugarloaf Point and Gabo Island have been studied. The shelf is divisible into inner (60 m), middle (60-120 m) and outer (120 m) zones. The surface sediments are dominantly quartz sands in the inner zone, kaolinitic mud/fine sands in the middle zone, and carbonate sands and gravels in the outer zone. Two distinct sediment sequences characterize the shelf sediment wedge. Basement structure is reflected in the present shelf morphology. The principal controls on geochemical

differentiation in the shelf sediments are depositional environment, provenance and effluent input. The manuscript of a Bulletin on this area was completed.

SKELETAL CARBONATE ON THE EAST AUSTRALIAN SHELF

by

J.F. Marshall

Sediments on the continental shelf of eastern Australia increase in carbonate content away from the present shoreline. However, the high values of the outer shelf sands show little latitudinal variation, both tropical and temperate continental shelves being mantled with sediments which are relatively pure carbonates. Thus a high calcimass productivity is not restricted to tropical regions. However, the types of carbonate-secreting organism do show marked latitudinal variations. North of latitude 24°S the outer continental shelf is dominated by the Great Barrier Reef, and inter-reef and outer shelf sediments contain the remains of hermatypic corals and calcareous green algae, mainly Halimeda, together with varying amounts of foraminifera, molluscs, bryozoa, and calcareous red algae. Corals and Halimeda are not present in the sediments south of 24°S, which consist of foraminifera, molluscs, bryozoans and calcareous red algae. The bryozoan content of the sediments increases to the south, and between 38° and 44°S bryozoans become the dominant component of the outer shelf sands.

Present-day sea-surface temperature and salinity data have been analysed to predict the distribution of carbonate particle associations. The observed distribution agrees with the predicted one, but the presence of relict carbonate sediments must be taken into account.

BARRIER REEF STUDIES - CAPRICORN AND BUNKER REEFS

by

P.J. Davies

Between 8th September and 13th October, seven reefs in the Capricorn/Bunker Groups were studied by three members of BMR (P.J. Davies, J.F. Marshall, D. Foulstone) and visiting scientists from the University of Sydney (B. Thom), Macquarie University (A. Short), James Cook University (N. Harvey) and the Queensland Institute of Technology (K. Martin). The seven reefs studied were Wreck, Masthead, Sykes, One Tree, Lamont, Fitzroy and Fairfax. The objectives of the expedition were -

1. To define, by geophysical methods and underwater sampling, the depth, shape and age of the unconformity on which the present reefs rest.

2. To determine the effects of the present-day hydraulic regime on the growth of the reefs.

3. To define the time framework of modern growth.

4. To study the physical and chemical changes involved in the reef lithification processes.

5. To estimate the potential for metal accumulation of reef sediments and to determine the time sequences of removal and deposition of metals in the carbonate sequence.

The M.V. Escape was chartered from Gladstone to provide the platform for field studies. Subsurface rock samples were collected by scuba diving to depths of 65 ft using the hand-held pneumatic drill described by Davies and Stewart (1976). The depth and shape of the unconformity on which the present reefs rest was determined by seismic refraction methods, and its extension between the reefs mapped by echo profiling. It is hoped that C^{14} and uranium-series dating methods will enable a precise correlation of the surfaces encountered beneath all the reefs studied.

The influence of the present-day hydraulic regime on the growth and extension of the reefs was attempted by measuring the wave and current energy impinging on the reefs and its resultant dissipation. Laboratory experiments will determine the sediment load carried under different sets of hydraulic conditions.

The development of reef islands was studied by surveying methods. Laboratory analysis of rock samples will outline the timing and nature of the processes involved in the growth and destruction of the reef islands. A novel and rapid method of sediment sampling was employed in the lagoon of Fitzroy Reef. A diver was towed on a manta board between sample locations, and immediately dived at the predetermined site. Preliminary results from echo profiling and seismic refraction suggest that the reefs of the Capricorn/Bunker Group rest on a hard indurated karst surface, the depth of which varies from reef to reef.

A paper on the evolution of One Tree Reef was published in the BMR Journal during the year.

DEEP SEA DRILLING

by

P.J. Cook

Indian Ocean Sediments

Samples were selected by P.J. Cook for a study of variations with time of the phosphate distribution in deep sea sediments of the Indian Ocean. Most of the samples have now been received from DSDP and analyses are underway. This work is being undertaken as part of the DSDP Indian Ocean Project which aims to take an overview of the drilling results from the Indian Ocean.

Timor Trough

Work on Timor Trough sediments by P.J. Cook, D. McKirdy (organic geochemistry), L. Chambers (inorganic chemistry), T. Donelly (S isotopes), and P. Trudinger (biochemistry), continued during the year. As a result of this continuing program a paper by McKirdy and Cook was presented on the results of the organic geochemistry. It was possible to conclude from this work that -

(i) The Timor Trough is partly anoxic.
(ii) The late Pliocene-early Pleistocene downwarp of the Trough is reflected in the geochemistry of the sediments.
(iii) The organic matter contains a significant land-derived component.
(iv) There is a marked increase in the proportion of land-derived material up the drill-hole.
(v) The sediments are thermally immature.
(vi) There has been a high level of in situ bacterial sulphate reduction.
(vii) The sediments of the Timor Trough are likely to generate oil and/or gas if subjected to higher temperatures and/or pressures.

Work related to bacterial activity within the sediment column is continuing.

MANGANESE NODULE FIELD OFF SOUTHWESTERN AUSTRALIA

by

N.F. Exon

In early 1976 the research vessel HMAS Diamantina dredged manganese nodules from the Southern Ocean floor. The cruise had been suggested by Dr L.A. Frakes of Monash University, who was in charge of the scientific program aboard ship. BMR provided most of the sampling gear, and was represented by Dr N.F. Exon. Mr J. Granath, a doctoral student at Monash, was the third member of the scientific contingent.

Dr Frakes was aboard the American research vessel Eltanin, when it took numerous bottom photographs in the area several years ago. The photographs revealed abundant nodules, and the results had been documented by Dr Frakes.

The Diamantina cruise lasted from 27.1.1976 to 5.2.1976, during which period the ship steamed about 1200 miles in the region south and west of Cape Leeuwin, and 9 sampling stations were occupied, 8 of them successfully. The apparatus used was a light box dredge on the ship's hydrowire, which has a breaking strain of about one tonne. Water depths ranged from 4300 m to 5000 m. Altogether about 2000 nodules were recovered, and bulk chemical analyses using the atomic absorption method were carried out on two samples of whole individual nodules from each station, by the Australian Mineral Development Laboratories. The results are summarized below.

The commercial interest in manganese nodules depends on their content of copper, nickel and cobalt, and the best of the above samples have higher nickel and copper contents than average. The combined copper, nickel and cobalt content of these nodules is, however, only about half that of nodules from the northeast Pacific between Hawaii and the USA, the area which is currently most promising.

The Diamantina and Eltanin cruises have shown that there are substantial nodule deposits over some 900 000 km^2 of deep ocean southwest of Australia, more than 200 miles from the Australian coast. The deposits occur as carpets of subspherical botryoidal nodules, which in places have amalgamated to form crusts, but are nowwhere more than one nodule thick. In the better areas the nodules average 5 cm in diameter. The nodules lie on a plain of soft red calcareous ooze, which shows signs of carbonate dissolution.

Station	Position		Water depth (m)	Nodule diameter (cm)	Average values for major metals (%)					
					Fe	Mn	Ni	Cu	Co	Ni+Cu+Co
1.	37°56'S	114°38'E	4900	No recovery	-	-	-	-	-	-
2.	40°03'S	114°10'E	4700	1	5.5	16.2	0.90	0.48	0.05	1.43
3.	41°53'S	113°57'E	4300	1-3	9.4	20.2	0.79	0.42	0.06	1.27
4.	37°57'S	103°09'E	5000	1.5-8	10.2	18.2	0.68	0.34	0.11	1.13
5.	37°00'S	102°55'E	4700	1.5-10	9.2	20.1	0.72	0.41	0.12	1.25
6.	36°00'S	102°00'E	4800	1.5-8	9.8	18.1	0.63	0.36	0.13	1.12
7.	35°54'S	99°03'E	4300	1.5-4	10.3	18.5	0.66	0.31	0.15	1.12
8.	34°58'S	98°58'E	4350	1.5-4	8.7	19.7	0.75	0.41	0.16	1.32
9.	34°38'S	101°00'E	4650	1.5-4	11.9	16.0	0.44	0.22	0.15	0.81

Analyses for a number of other metals were also carried out, yielding the following unexceptional average values: Pb, 0.053%; V, 0.041%; Ti, 0.48%; Au, approx. 0.01 gram/tonne; Pt, approx. 0.04 gram/tonne.

Far too few samples have been collected for any general assessment of this potential mineral resource to be made. However, the information now available justifies further investigations which will be carried out as the opportunity arises. A full report of the cruise is to be published in the BMR Journal in early 1977.

THE FORMATION OF OOIDS

by

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

Experimental work on the physico-chemical conditions governing the formation of carbonate ooids was carried out in collaboration with the Baas Becking Geobiological Laboratories.

Ooids have been discovered at two localities in the Great Barrier Reef Province, viz. in the Capricorn Channel in the south and at Lizard Island in the north. The Capricorn Channel ooids are composed of high-magnesium calcite, while those from Lizard Island are aragonitic. Both display a cortex composed of alternating layers of radially orientated carbonate prisms and organic/amorphous carbonate matrix. The prismatic layers are characterized by an open porous structure, with spaces between adjacent crystals. The organic material, which is primarily protein, makes up 0.5 percent of the ooid.

At the Lizard Island site pH, salinity, alkalinity, calcium, potassium, sodium and sulphate values are close to those of standard sea water. However possible variations from such conditions may occur over short periods during low spring tides or neaps in January or February. Diurnal cyclical variations in pH, alkalinity and oxygen in these waters of the inner reef flat testify to the photosynthetic and respiration cycles of the diverse communities inhabiting the area. Although the sites where the ooids were discovered are subject to semidiurnal tidal flow and therefore agitation, sediment stabilization is far advanced owing to the spread of seagrasses and organic coatings. Analysis of the suspension load during flood tide conditions coinciding with 20-30 knot winds revealed only coral, coralgal and quartz detritus. No coated grains were recorded.

Petrographic studies and field observations both suggest that ooid grains have not been agitated greatly within their depositional environment.

The presence of a substantial organic component in the Great Barrier Reef ooids, and in ooids reported from the Bahamas and the Persian Gulf has stimulated laboratory experimentation

into ooid growth, coupling organic additions to seawater-type solutions. Negative results were obtained from solutions containing neutral or acidic amino acids, short homogenous and heterogenous amino acid polymers, intermediate molecular weight proteins (M.W. 14 000), algal mucilage, soil fulvic acids, algal protein, and bacterial cell walls.

Successful laboratory formation of ooids or spherulities was obtained from solutions containing either humic acids, synthetic condensates of amino acids and glucose and extracted fractions of Bahamman ooids. Scanning electron microscopic study of the ooids and spherulities showed a concentric alternation of layers of radially orientated aragonite or calcitic prisms and organic/amorphous carbonate. Acidification of the ooids showed the organic layers to be membranous, three or four occurring within one ooid. The formation of such membranes may therefore provide the key to the periodicity seen in synthetic and natural ooids. The negative results suggest either the requirements of a highly specific organic component, the necessity for some other general character in addition to the presence of functional groups which have the ability to react with carbonate, or that the organic material is an incidental impurity rejected during crystal growth within the modern ooid. It is possible that the necessary prerequisite for ooid growth is the formation of organic membranes. Such membranes may have two functions; either their undersurface may inhibit further crystal growth, or their upper surface, through the availability of functional groups, may promote crystal growth. Whether initial heterogeneous nucleation is epitaxial or not may then determine the orientation of precipitated crystals. The laboratory experiments were conducted under conditions of agitation and non-agitation, in normal saline and hypersaline solutions. Successful ooid growth occurred in both saline and hypersaline solutions under conditions of minimum agitation.

A paper recording the discovery of aragonitic ooids at Lizard Island was published during the year by Davies and K. Martin (Queensland Institute of Technology).

URANIUM-SERIES DATING

by

J.F. Marshall

Isotopic dating by the uranium-series method was carried out on coralline material from several areas using laboratory facilities provided by the Research School of Earth Sciences, A.N.U.

Corals from the Capricorn Group and Hayman Island within the Great Barrier Reef province show relatively young ages. One coral recovered by drilling at a depth of 17 m on the Hayman Island reef indicates that the time of recolonization of the reef towards the end of the Holocene transgression is about 8300 yr B.P. Coral samples below a marked discontinuity at a depth of about 20 m are extensively recrystallized.

Ages of corals from the Inner Barrier of New South Wales show that this feature formed during the last interglacial at about 120 000 yr B.P. The ages suggest that there were two periods of high sea level at about this time. The unwarped interglacial deposits indicate that sea level was 5 $\pm$ 1 m higher than the present.

Ages from reef terraces 2 to 6 m above present sea level from three islands of the Loyalty Archipelago show the varying degrees of uplift of these islands. Corals from +2 m on Beautemps-Beaupre are older than 200 000 yr B.P., and a coral at +6.5 m from Ouvea gave an age of 117 000 $\pm$ 6000 yr B.P. Ages from the +2 m terrace on Lifou support the interpretation of a relatively high sea level at about 180 000 yr B.P.

Ages of corals from a slightly raised fringing reef around Mud Island, Moreton Bay indicate a sea level about 1 m higher than present during the interval 4000 - 6000 yr B.P. This slightly higher sea level could have been the result of a changing tidal regime within the bay.

MARINE GEOLOGY LABORATORY

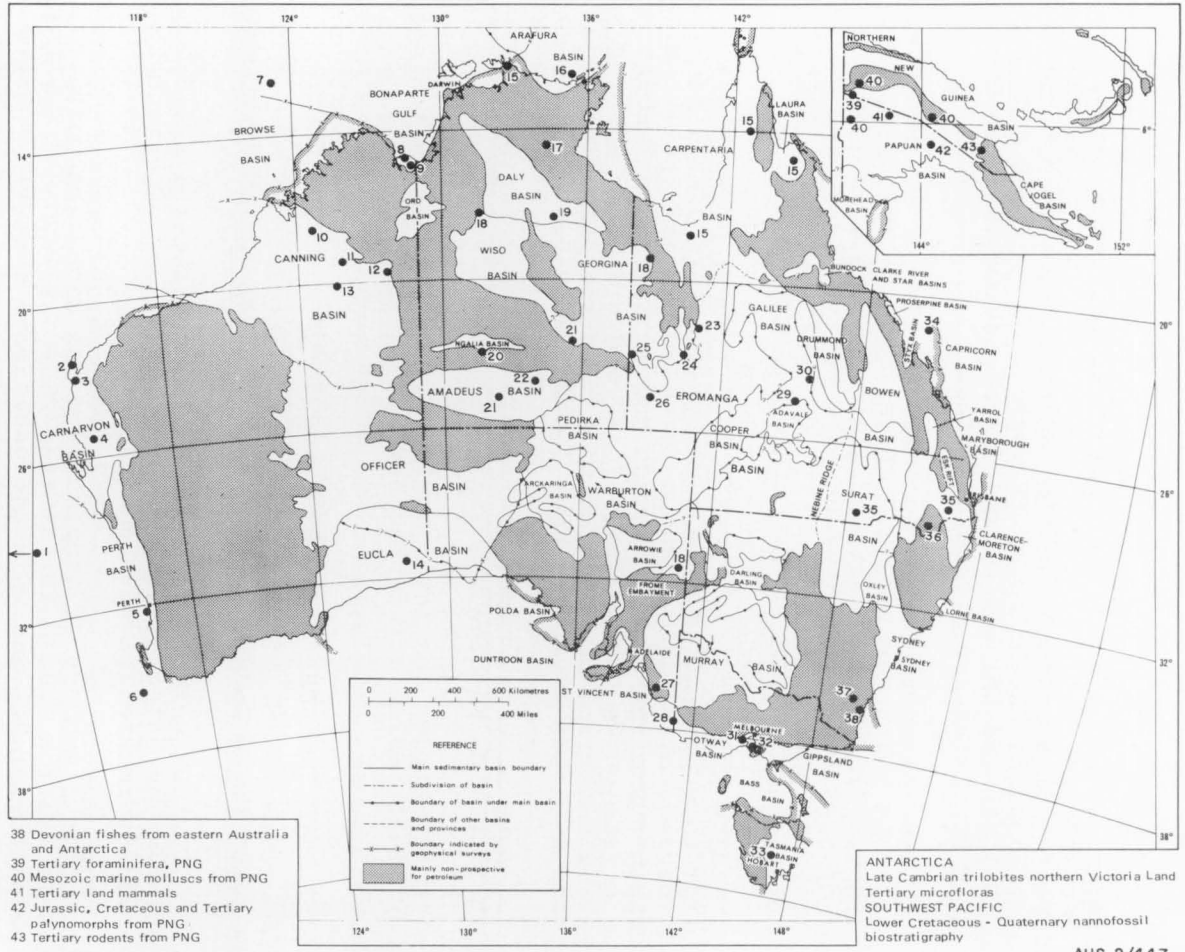
STAFF: M.H. Tratt, B.G. West, D. Foulstone, L. Pain, C. Robison

Grainsize analyses of Tasmanian continental shelf sediment samples using sieving, settling tube and pipette methods continued intermittently throughout the year.

Large numbers of samples from the Robe-Naracoorte drilling operation, and material from DSDP Indian Ocean boreholes, were prepared for XRD analysis and peak areas measured. Heavy mineral separations on continental shelf material and on sands from the coastal dune sequence of southeast South Australia were carried out.

Work outside the main activities of the laboratory which occupied considerable time during the year included operation of the Scanning Electron Microscope (C. Robison), and cataloguing and indexing bathymetric data and seafloor samples supplied by the Navy (M. Tratt).

1 Eocene nannofossils, Ninetyeast Ridge
2 Oligocene and Miocene larger and planktonic foraminifera
3 Upper Cretaceous-Eocene nannofossil biostratigraphy
4 Palaeozoic conodonts, Carnarvon Basin
5 Santonian, Palaeocene & M.Eocene nannofossils
6 Eocene nannofossils Naturaliste Plateau
7 Miocene larger & planktic foraminifera Upper Oligocene-Lower Miocene nannofossils
8 Late Cambrian trilobites, Bonaparte Gulf Basin
9 Lower Carboniferous ostracods from the Bonaparte Gulf Basin
10 Lower Carboniferous and Upper Devonian ostracods, Canning Basin
Upper Devonian and Lower Carboniferous conodonts from the Canning Basin
Upper Devonian and Lower Carboniferous fishes from the Canning Basin
11 Permian invertebrate faunas including ichnolites
12 Lower Ordovician Dikelokephalinidae from northern Australia
13 Upper Palaeozoic and Mesozoic plants
14 Middle Eocene nannofossils
15 Cretaceous marine molluscs from northern Australia
16 Middle Cambrian trilobites, Elcho Island
17 Precambrian stromatolites and microfossils
18 Tertiary mammals from N.T., Qld and S.A.
19 Agnostid trilobites from N.T. and N.S.W. Middle Cambrian trilobites of northern Aust
20 Tertiary pollen grains, Ti Tree area
21 Biostratigraphy of Upper Devonian vertebrates in Amadeus & Georgina Basins
22 Late Cambrian and early Ordovician rostroconchs; early Ordovician pelecypods
23 Late Cambrian trilobites (Chatsworth)
24 Late Cambrian and early Ordovician trilobites and conodonts, Georgina Basin
25 Early Devonian thelodont fish scales Toko Range
26 Palynology of the Toolebuc Formation
27 Silicification of modern algae
28 Eocene nannofossil biostratigraphy
29 Palynology of the Ronlow Beds
30 Permian spores and pollen, Galilee Basin
31 Miocene larger foraminifera
32 Lower - Middle Miocene nannofossils
33 Permo - Carboniferous spores and pollen, Tas.
34 Eocene - Oligocene nannofossils Coral Sea Basin. Oligocene - Miocene larger foraminifera
35 Early - Cretaceous spores, pollen and microplankton from the Surat Basin (Qld)
36 Permian fauna from the Warwick area
37 Silurian conodonts, Canberra region Silurian encrinurid trilobites of south eastern Australia. Silurian brachiopods and biostratigraphy of the Canberra region



38 Devonian fishes from eastern Australia and Antarctica
39 Tertiary foraminifera, PNG
40 Mesozoic marine molluscs from PNG
41 Tertiary land mammals
42 Jurassic, Cretaceous and Tertiary palynomorphs from PNG
43 Tertiary rodents from PNG

ANTARCTICA
Late Cambrian trilobites northern Victoria Land
Tertiary microfloras
SOUTHWEST PACIFIC
Lower Cretaceous - Quaternary nannofossil biostratigraphy

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Fig. S6. Current palaeontological projects

PALAEONTOLOGICAL STUDIES (Fig. S6)

The Groups' involvement in the 25th International Geological Congress is referred to where appropriate in the individual reports. Between the end of June and the end of September approximately 30 oversea palaeontologists visited the group either to examine the collections or for scientific discussions. Many of the visitors were in Australia to attend the Geological Congress.

G.C. Young continued his work on Devonian fish from Australia and Antarctica at the British Museum (Natural History) and University of London under an Australian Public Service Scholarship. He visited institutions in United Kingdom, Norway, Sweden and Germany and USSR to examine research collections and for discussions with other scientific workers and attended a conference on Silurian and Devonian fishes at Tallinn, Estonia. He is scheduled to return to Canberra in December 1976.

Arrangements were made for Dr R.A. Fortey of the British Museum (Natural History) to collaborate with the Georgina Basin Field Project. He will work on part of the Ordovician trilobite fauna and participated in the field work. Collaboration has continued with Dr M.D. Muir of the Imperial College, London, on Precambrian microfossils.

Work on the organization of collections has continued and has resulted in making the collections far more readily available for use, but a great deal of work yet remains.

ACTIVITIES

J.M. Dickins

Collaboration in the Canning Basin Geological Mapping Project has continued and field work was carried out with the party. Two faunas have been recognized in the Upper Permian (Hardman Formation). Both faunas have species in common which distinguish them from the underlying Lower Permian fauna (Lightjack Formation).

A paper "Permian Gondwana Climate" was prepared and delivered at the 25th International Geological Congress. Meetings attended or organized at the Congress were the Commission on Stratigraphy, Subcommissions on Gondwana and Permian Stratigraphy and the Working Group on Climate of the Permian Subcommission. Help was given in the preparation of the Bowen Excursion 3C and responsibility for acting as a guide for Excursion 3C Special was undertaken. This excursion was organized during the Congress and took place in southeastern and central eastern Queensland.

The paper "Permian Climate of Australia" has been offered to Palaeogeography, Palaeoclimatology, Palaeoecology and changes are being made according to the referees' comments. Work is continuing on a keynote paper for the IV International Gondwana Symposium (jointly with S.C. Shah, Geological Survey of India) on the correlation of the Permian marine faunas of India and Western Australia. Work has also continued on the Permian fauna of the Warwick area, Queensland.

M. Plane

Work continued on fossil mammal faunas from Bullock Creek, Northern Territory, Riversleigh in Queensland and Lakes Ngapakaldi and Pinpa in South Australia.

A paper summarizing the important new middle Tertiary finds at sites in the Frome Embayment was prepared in conjunction with R.H. Tedford of the American Museum of Natural History. It was delivered at the IGC. The paper has been expanded and is now in press.

Preparation of the Carl Creek Limestone, from Queensland, has produced yet another new record of a small, and as yet unnamed and unpublished kangaroo, known previously from the Lake Eyre Basin. This taxon further strengthens the correlation between the Lake Eyre Basin and northern fossil mammal sites.

S.K. Skwarko

S.K. Skwarko completed four papers on molluscan faunas of Mesozoic age collected over the last several years both in northern Australia and Papua New Guinea. Concurrently he continued preparations for the revision of Australian Cretaceous ammonites and bivalves.

He participated in a 5-week international fossil-collecting trip to the Sula Islands, Indonesia. His study of the collected material will assist in a more thorough and accurate interpretation of the Mesozoic palaeontology, palaeogeography and biostratigraphy of Australia and New Guinea. His other duties included the updating of the computerised index of palaeontological literature dealing with Mesozoic molluscs and Ordovician graptolites.

D.L. Strusz

D.L. Strusz is engaged in a stratigraphic and palaeontological study of the Palaeozoic rocks of the ACT and surrounding districts. This will be a contribution to the background information necessary to understanding the tectonic and metallo-

genic evolution of the Lachlan Geosyncline. The stratigraphic work is in cooperation with the Geological Survey of New South Wales, and within BMR with the Engineering Geology Group; detailed work is being done in the Tantangara and Brindabella 1:100 000 Sheet areas by a team under M. Owen, and in the Canberra 1:100 000 Sheet area by R.S. Abell.

Palaeontological work is concentrated on the Silurian rocks - and thus is also a contribution to Project Ecostratigraphy, a category 'A' project of the I.G.C.P. For some time, work will be concerned with documenting Silurian faunas from a variety of horizons, so as to build up a usable biostratigraphic framework. The first part of this work has been a study of the trilobite family Encrinuridae, a widespread group much in need of revision. This study is now in final stages of photography and writing. A broader study, of the brachiopod faunas, has started with collections of well-preserved material from a small area west of Canberra; preliminary work was done at Swansea (UK) while on furlough in 1975, and more material has been subsequently prepared, adding somewhat to the fauna. Photography and writing has started, and necessary comparison with types of known species from the Yass area has been done.

Further activities were::

1) Helping to organize, write notes for, and run Excursion 12B for the 25th I.G.C.

2) Guiding visiting specialists in collecting from the Silurian and Lower Devonian of Yass and the Burrinjuck Reservoir.

3) Membership of the Editorial Board for the Geological Society of Australia.

4) Australian correspondent for the newsletter 'Fossil Cnidaria' of the International Research Group on Fossil Corals.

J.H. Shergold

J.H. Shergold continued the systematic description of Late Cambrian trilobites from the Burke River area, western Queensland. Some 54 taxa have been recognised from Chatsworth Limestone occurring as pediments on the plains NW of 'Chatsworth' and in sections along the Mort River at Horse Creek and Lily Creek. These taxa are of Late Cambrian, post-Irvingella, Daizanian age: they permit a rigorous reappraisal of the Asian Daizanian and Changshanian Stages. A further 32 taxa of trilobites occur at Mount Murray, about 35 km NW of 'Chatsworth'. These are of Idamean and immediate post-Idamean ages, and are

being described in a general revision of the Idamean faunas of the Burke River area. Related to the distribution of Late Cambrian trilobites in this area, core from BMR Boulia No. 6 (Lily Creek) was examined and found to represent subsurface the duration of the Horse Creek outcrop area, and examination of BMR Duchess No. 13, which commences in equivalents of the Lily Creek section, is continuing.

Other continuing activities include: (1) examination of macropalaeontological samples collected by the Georgina Basin project (165); (2) the supervision of ANU PhD candidate, P. West, whose thesis involves the Middle Cambrian biostratigraphy of the Arthur Creek and Marqua Beds of the Huckitta-Marqua area; and (3) examination of Late Cambrian trilobites from northern Victoria Land, Antarctica, supplied by the New Zealand Antarctic Survey Expeditions and worked in collaboration with R.A. Cooper (New Zealand Geological Survey) and J.B. Jago (South Australian Institute of Technology) under the IGCP SW Pacific Basement Correlation project.

In connection with Georgina Basin Project activities, a study of the trilobite faunas of the Early Ordovician Nora Formation has been initiated as a joint project with R.A. Fortey (British Museum, London). The Nora Formation represents a major transgressive event, inundating the Australian craton during late Arenig time. Some 22 taxa have been recognised and collected from measured sections primarily in the Toko-Toomba Ranges.

During the year, visits were paid to: (1) New Zealand, where Cambrian and Lower Ordovician sequences were examined in the NW Nelson region of South Island, and the collections of the New Zealand Geological Survey appraised in Lower Hutt; (2) central Victoria, to participate in an IGCP SW Pacific Basement Correlation field meeting to examine the Cambrian-Ordovician boundary sequences of Lancefiled, Heathcote and Mount Wellington; (3) South Australia, to examine sequences crossing the Cambrian-Precambrian boundary south of Adelaide and in the Flinders Range, in co-operation with the IGCP Precambrian/Cambrian boundary project of J.W. Cowie (University of Bristol).

Throughout the year preparations were made for the 25th International Geological Congress, most of this effort being directed into the compilation of a guidebook for field excursion 4C, which was co-led after the Congress in Sydney. During the Congress proceedings, meetings of the IUGS Subcommission on Gondwana Stratigraphy Early Palaeozoic Working Group and the IUGS Cambrian/Ordovician Boundary Working Group were convened, and there was further participation in the activities of the Cambrian Subcommission (Cambrian Correlations Working Group) and the Ordovician Subcommission (acting Secretary). A submission, compiled from contributions from R.A. Cooper (NZGS), E.C. Druce (BMR),

B.D. Webby (Univ. Sydney) and J.H. Shergold (BMR), and providing a synopsis of Cambrian/Ordovician boundary sections in Australia, New Zealand and Antarctica, was presented to the Cambrian/ Ordovician Boundary Working Group.

Three papers were published, and one Record issued, during the year: two papers are in press. A contribution to the Elsevier book 'Lower Palaeozoic Rocks of Australasia', on the geology of the Georgina Basin, is currently under compilation.

J. Gilbert-Tomlinson

J. Gilbert-Tomlinson made preliminary identifications and datings of Cambrian and Ordovician fossils collected by the Wiso Basin Party for stratigraphic and palaeogeographic guidance in compiling Explanatory Notes to 1:250 000 map sheets within the basin.

Subsequent re-examination of conodonts (by E.C. Druce) confirms the presence of two distinct Ordovician faunas with the Basin. The older one is not represented by macrofossils in existing collections and hence its palaeogeographical significance cannot yet be determined. The fossils now known from the Basin represent at most 7% of the zonal sequence of the interval from Middle Cambrian to Middle Ordovician established for other parts of northern Australia.

Collections made by the A.A.E.C. in the area of Katherine in the Daly River Basin were examined and the results of examination for microfossils by M.R. Walter and R.S. Nicoll were amalgamated in a report on the possible age and environment of the deposit, believed to be early Middle Cambrian.

The division of the northern Australian post-Tremadocian Ordovician into stages is progressing and will be included as a stratigraphic background to the current systematic paper on Dikelokephalinid trilobites. The Bulletin on Dikelokephalinid trilobites is planned to be finalized early in 1977.

Photography of trace fossils is well under way and literature search is complete for two papers, to be published externally, on Early Palaeozoic and Late Palaeozoic/Mesozoic Australian ichnolites.

The geological background to a paper on Australian Ordovician vertebrates has been contributed for a joint paper with Alexander Ritchie (Australian Museum, Sydney) to be published externally.

D.J. Belford

D.J. Belford's study of Tertiary foraminifera from the Blucher Range and Wabag 1:250 000 Sheet areas, Papua New Guinea has been suspended, pending the receipt of a sample locality map for the Wabag Sheet.

Study of a large foraminiferal/planktonic foraminiferal assemblage from the Kavieng 1:250 000 Sheet area was begun. The larger foraminifera are well-preserved, and are believed to be autochthonous; it is intended to make a biometric study of this group, to relate the degree of development of the nucleoconch to the planktonic foraminiferal zonation. Support was given to the Papua New Guinea Geological Survey during the year, in connexion with their mapping projects.

Curation of the foraminiferal collection continued, mainly that dealing with Western Australia and Papua New Guinea. In conjunction with the ADP group, efforts to develop a computer-based data retrieval system for the palaeontological collections continued.

Establishment of the ESCAP fossil reference collection continued. Additional foraminiferal specimens were deposited and also latex moulds of South Australian Precambrian fossils.

P.J. Jones

P.J. Jones is engaged in biostratigraphic studies aimed at the refinement of the Carboniferous and Devonian time scales, by comparing faunal sequences from Australia with those from overseas. To date, this work has involved mainly platform rather than geosynclinal provinces.

The MS on the Lower Carboniferous Ostracoda from the Bonaparte Gulf Basin is now being revised in the light of results of a concurrent study of ostracods collected from reference sections of Lower Carboniferous (Dinantian) rocks in Belgium, northern France, and the USSR (Moscow Basin, and the South Urals). Such first-hand comparison of ostracod faunas helps to remove some of the doubts involved with intercontinental correlation.

Two review papers on the Carboniferous System have been published (i) 'Some aspects of Carboniferous biostratigraphy in eastern Australia: a review' - with J. Roberts (School of Applied Geology, University of NSW), and (ii) 'The Silesian in Australia - a review' - with E.C. Druce.

Some of the Carboniferous sequences of eastern Australia were examined in the field with D.T. Crane (University of NSW), T.B.H. Jenkins (University of Sydney) and B. Mamet (University of

Montreal) to collect limestone samples from various localities in the Hunter Valley and Belvue Syncline, NSW, and the Yarrol Basin and Rockhampton area of Queensland. These samples are being examined for microfossils (foraminifera, ostracods, and conodonts). One of the objects of this type of work is to attempt to calibrate the different zonal scales based on various fossil marine invertebrate groups. A preliminary result is the recognition of brachiopods of the Schellwienella cf. burlingtonensis Zone within the Gnathodus semiglaber conodont zone in the Carellan sequence of Jenkins (1974).

Work continued on the description of the microfauna found in the limestone and siltstone beds which overlie Ordovician rocks, and are themselves overlain by the Craven Peaks Beds in the Toko Range of the Georgina Basin. The microfauna consists of theolodont scales - Turinia australiensis Gross and T. pagei (Powrie) - which indicate an Early Devonian (Dittonian) age, abundant eridostracans - Cryptophyllus - and some ostracods. This project is being undertaken, in collaboration with Susan Turner (The Hancock Museum, Newcastle-upon-Tyne, UK) and J.J. Draper, as a contribution towards the knowledge of the palaeogeography and the age of tectonic activity in central Australia during the Devonian Period.

E.M. Truswell

E.M. Truswell completed a series of papers dealing with the palynology of Tertiary sediments on the Ninetyeast Ridge, Indian Ocean. The last of these, a major taxonomic study of dispersed pollen and spores at Sites 214 and 254 on the ridge crest, was completed in 1976 in co-operation with W.K. Harris of the Department of Mines, South Australia, and is now in press as a special paper of the Palaeontological Association, London.

During the year a program of investigation of the age and depositional environment of lignites in the southern part of the Northern Territory was begun. Lignites in a BMR stratigraphic borehole in the Napperby Sheet area were identified as being of middle Eocene age; those subsequently examined from the nearby Ti Tree Basin have been tentatively identified as Miocene. Recently, data from the Ayers Rock area have suggested that lignitic sediments in that area may be Palaeocene. These preliminary results suggest a sequence akin to that which is present in northern and central South Australia, where deposition of lignitic sediments took place in the Palaeocene and Eocene, as exemplified in the Eyre Formation, and occurred again in the middle Miocene, as evidenced by the Etadunna Formation. These periods of deposition coincided probably with intervals of high temperatures and consequent high precipitation; palaeomagnetic studies in the Eromanga and Surat Basins of Queensland offer independent evidence that the Palaeocene-Eocene and early-middle Miocene were times of deep weathering, associated probably with high rain-

fall conditions. An account of the palynological assemblages from BMR Napperby 1 was published during 1976 (BMR Journal 1(2), 109-114); detailed work is presently underway on the Ti Tree and Ayers Rock lignites (the latter in conjunction with W.K. Harris).

Several months were spent in 1976 in the preparation of a review paper which integrates Tertiary palaeoclimatic data from Deep Sea Drilling Program drillsites in the Southern Ocean with palynological data relating to the vegetation history of Australia and Antarctica. Using as climatic parameters deep-sea data relating to surface water temperatures, to the extent of Antarctic ice-cover, and to the position of land and sea areas during the Tertiary, a series of palaeoclimatic maps was constructed, showing the possible patterns of atmospheric circulation. The palynological data have been fed into these to check the correlation of inferred vegetation types with the suggested climates. The essence of this review was presented at the International Geological Congress in Sydney in August (IGC Abstr. 1, p. 328); the manuscript is intended for publication in Palaeoclimatology, Palaeogeography, Palaeoecology.

Work on Palaeozoic palynology during 1976 included involvement in a study of the Brewer Conglomerate, Amadeus Basin; further work on the Galilee Basin palynology project; the organisation of a symposium on 'Early Gondwana Stratigraphic Palynology' at the 4th International Palynological Conference in Lucknow, India, and the preparation of a review of Australian Permo-Carboniferous palynology for presentation at that conference. The Brewer Conglomerate study, carried out in conjunction with G. Playford, of the University of Queensland, and B.G. Jones, of the University of Wollongong, established a Late Devonian (pre-late Famennian) age for the Brewer Conglomerate, the uppermost formation of the Pertnjara Group. This formation is considered to be synorogenic in origin, so these data suggest that the Alice Springs Orogeny commenced in the Late Devonian; isotopic age determinations have hitherto suggested that tectonic activity was confined to the Early Carboniferous (Alcheringa 1 (2), 235 - 243).

Work on the Galilee Basin palynology project, being carried out in conjunction with the Geological Survey of Queensland, was delayed to July by travel restrictions. However, sample material was collected from the continuously cored GSQ drillsites Jericho Nos. 1 and 2 and GSQ Springsure 13. Much of this material has now been processed, with good palynological yield from formations of the Joe Joe Group, and work on the taxonomy of palynomorphs from this Late Carboniferous interval is underway.

For the symposium, 'Early Gondwana Stratigraphic Palynology' at the Lucknow conference, a series of six papers dealing with the stratigraphic palynology of the Late Carboniferous and Permian of all the Gondwanaland continents has been collected. The papers include review papers from South America, papers dealing with individual coal basins in India and southern Africa, a contribution dealing with the palynology of the northern margin of Gondwanaland in Irian, and a review dealing with Australia and Antarctica. Authors of the last review include B.E. Balme, R.J. Helby, E.M. Truswell, P.L. Price and R.A. Kyle; the review outlines the development of an eightfold division of the Canning Basin Late Carboniferous and Permian, the recognition of four zones in the Carboniferous of the Bonaparte Gulf Basin, and the modification of the palynological zones of Evans in several eastern Australian basins, including the Galilee, Cooper, Sydney and Tasmania Basins. A section describing the state of the palynologic art in Antarctica is also included, which sets out those areas in which Australian palynological zones have been identified.

D. Burger

D. Burger completed the draft of a Bulletin entitled "Palynological studies in the Cretaceous of the Surat Basin, Australia". This study serves as the base for further biostratigraphic work in the much more sparsely sampled rock sequences of the Eromanga and Carpentaria Basins in Queensland and Northern Territory, and summarizes information accumulated over fifteen years.

Apart from detailed taxonomic and descriptive work on the spores, pollen grains, dinoflagellates, acritarchs, and chlorophyta, stratigraphic aspects are discussed at length. The spore-pollen zones are outlined in Table S2. Accurate checks on range limits of various critical species, particularly in the Albian, provide further agreement with recently published pollen data from the Otway Basin, Victoria, and correct previous opinions on the incoming of the oldest known angiosperm pollen in Australia.

Owing to the marginal environments the marine record is restricted to the Minmi Member, Doncaster Member, Coreena Member, and certain horizons in the Surat Siltstone. Two dinoflagellate zones (instituted by R. Morgan, Geological Survey of New South Wales) are recognized: the Odontochitina operculata Zone and the Pseudoceratium turneri Zone, each defined by the first appearance of the nominate index species.

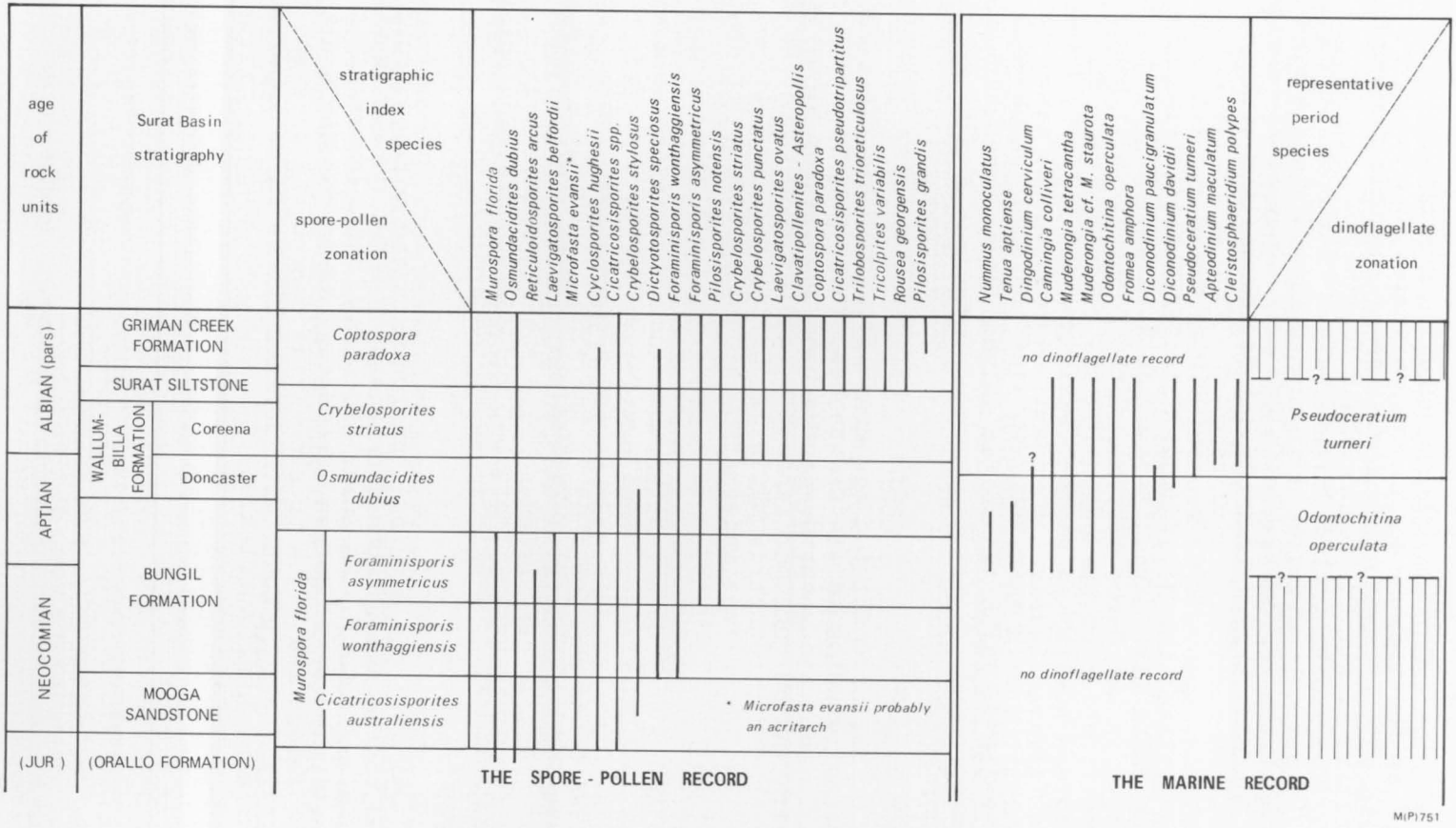


Table S2. Distribution of Early Cretaceous palynomorphs in the Surat Basin, Queensland.

The presence of fossils of both nonmarine and marine origin in the palynomorph preparations was put to practical use in retracing palaeo-environments during the Aptian and Albian. A tentative correlation formula was drawn up to translate mutual proportional numbers of these organisms into depositional environments of the associated sediment. Based on these correlations a series of palaeogeographic maps were drawn. According to these maps a brief marine phase occurred in the Surat Basin (in late Neocomian time), presumably during an easterly incursion of the sea. During the Aptian the sea again penetrated from the west to northwest and gradually flooded the entire basin. Successive stages of retreat of the sea during the early and middle Albian were recorded in the Surat Basin only; the Albian "Tambo Sea" persisted in central and northern Queensland.

With the unexpected discovery of monosulcate and tricolpate angiosperm pollen in lower and middle Albian sediments of the Surat Basin the question of the origin of the parent floras arose, and a literature study was made to seek evidence as to the origins and migratory patterns of the earliest angiosperm floras, and Australia's role in their development.

Preliminary conclusions were discussed in a short paper entitled "Observations on the earliest angiosperm development with special reference to Australia", and which is to be presented at the IVth International Palynological Conference (Lucknow, December, 1976). It is thought that the oldest recorded angiosperm floras emerged in tropical areas and rapidly colonized the warm-temperate zones of the earth, before penetrating into regions of higher palaeolatitudes.

There are vague indications for an (eastern) Asian origin of the earliest Australian angiosperms. From reconstructions of the continents for the Early Cretaceous it is not apparent that a connection existed between Australia and Asia, although the occurrence of similar pollen floras in Siberia and Australia suggest that a connection existed at the time.

M.R. Walter

Georgina Basin project. The lithology and palaeontology of the late Precambrian and Early Cambrian sedimentary rocks of the Huckitta, Alcoota, Barrow Creek and Mount Peake 1:250 000 Sheet areas were studied. The results of this work are described elsewhere in this summary.

Amadeus Basin stromatolites and cherts. The continuing study of stromatolites from the Amadeus Basin will facilitate correlations with the Georgina Basin. A project was commenced in cooperation with J.F. Truswell to study the sedimentology of the Bitter Springs Formation. Particular attention is being given to the origin of the microfossiliferous cherts. Preliminary indications are that the cherts are early diagenetic and formed in an upper intertidal to supratidal environment.

Nabberu Basin. The first results of the study of microfossils from oncolites in the Frere Formation (iron formation) were published during the year.

International Geological Correlation Programme - Working Group on Upper Precambrian Correlations. Correlation charts were prepared for the Australian Adelaidean. These contain all pertinent palaeontological, geochronological, palaeoclimatic and sedimentological information. They were displayed and discussed during a meeting of the international and local working groups in Sydney during the IGC. They will be prepared for publication.

International Geological Congress. Section 1B ("Life in the Precambrian") was convened by Walter and was very successful. Papers presented during that section have been prepared for publication in a special issue of "Precambrian Research" which has been edited by Walter. Walter presented a lecture in this section and also contributed to the meeting of the Precambrian-Cambrian Boundary Working Group (IUGS). He chaired the meeting of the IGCP Working Group on Upper Precambrian Correlations.

"Stromatolites", Elsevier Publ. Co. Editing of this book was completed and it was published during August. It consists of 44 chapters, 4 appendices, a bibliography and an index, is 790 pages long, and was contributed to by 42 authors, and sells for $95.

Future role of palaeomagnetism in BMR projects. Membership of a committee considering this subject involved considerable time. It has been decided to greatly expand the activities of the organisation in this field.

Secretaryship of the Association of Australasian Palaeontologists. Much time was spent organising the affairs of the Association and ensuring its financial viability. The second issue of "Alcheringa" was published during the year.

R.S. Nicoll

Robert S. Nicoll completed, with E.C. Druce a study of the conodonts from the Fairfield Group, Canning Basin, WA. Conodonts from the Fairfield are representative of Upper Devonian and Lower Carboniferous strata. Nicoll continued the studies on Devonian conodont faunas from the Oscar and Napier Ranges of the Canning Basin and the Gneudna Formation of the Carnarvon Basin.

His study of Silurian conodont faunas from the ACT and adjacent areas of NSW continued but only spot samples have been so far obtained. Reference material has been processed from localities listed by Link & Druce (1972, BMR Bull. 134) Recovery of specimens is encouraging.

A study of the origin of the London Bridge karst feature was undertaken with J.N. Jennings (ANU) J.B. Brush (Dept Nat. Res.) and A.P. Spate (CSIRO). The result are now in press with the Australian Geographer.

G.C.H. Chaproniere

G.C.H. Chaproniere commenced a study of the planktic foraminiferids in the Oligo-Miocene part of the Ashmore Reef No. 1 well in the Bonaparte Gulf Basin. This is, in part, a joint study with S. Shafik, who is describing the nannofossils. The biostratigraphic ranges of some of the species are earlier than previously recorded. The index fossil for Blow's Zone N. 4 is Globigerinoides quadrilobatus primordius; this taxon overlaps with Globorotalia opima opima, the extinction of which defines the base of Zone N. 3. This overlap in ranges has led to the suggestion that Zones N.3 and N.4 be combined. Furthermore, the initial appearance of Globigerinoides quadrilobatus primordius has been suggested as marking the Oligocene-Miocene boundary. The results of this study indicate that the first appearance of Globigerinoides probably antedates the base of the Miocene at the type section in Europe. The nannofossils support a late Oligocene age for this section in Ashmore Reef No. 1 Well. These results will be published in a paper to be submitted to the BMR Journal. A second paper, dealing with the systematics of the planktic foraminiferids will be submitted to the BMR Journal shortly.

A specimen of a larger foraminiferid, identified as Lepidocyclina in a DSDP report for Leg 30, was forwarded to the writer. This specimen was associated with an Eocene planktic foraminiferal fauna. The genus Lepidocyclina has not been recorded previously from the Eocene in the Indo-Pacific region, and so any record of this genus from these levels is of considerable biostratigraphic and palaeogeographic importance. Detailed examination of the specimen showed it to be an Eocene form, Asterocyclina sp. cf. A. centripilaris. These results form a short note to be published in an outside journal.

The study of Oligo-Miocene larger foraminiferids from the northwest of Western Australia is completed and a manuscript is being prepared as a BMR Bulletin.

A paper establishing a new unit, the Bullara Limestone, was published in the BMR Journal.

Samir Shafik

Otway Basin. Nannofossils from four localities in the Otway Basin revealed the occurrence of a marine middle Eocene horizon. In the Gambier Embayment, a barren section separates this horizon from an upper Eocene marine sequence, but in the

Engineering & Water Supply Beachport No. 1 Bore, the horizon is directly overlain by marine Oligocene sediments. In the Port Campbell Embayment, the middle Eocene horizon has also been detected.

The horizon may represent ingressions preceding the major upper Eocene transgression which occurred over most of the southern Australian margin, but it may also be regarded as the final phase of a more intensified transgression (middle Eocene in age) which was isochronous in covering a vast area extending from Pakistan to southern Australia (its peak in the latter was over the Eucla Basin). Nannofossil evidence indicates that deposition of the middle Eocene horizon in the Otway Basin was in a shallow nearshore environment, and that surface-waters were probably warm. A few Upper Cretaceous forms have been recorded from the horizon in the Port Campbell Embayment. These are presumed to have been reworked, probably from a western source (? the Naturaliste Plateau off southwestern Australia).

Bonaparte Gulf Basin. Nannofossil evidence suggests that the planktic foraminiferid Globigerinoides quadrilobatus primordius datum is late Oligocene in age contrary to the unratified recommendation of the Neogene Committee (at Bologne, 1967). This substantiates an earlier suggestion that this datum should be placed at the N.2/N.3 zonal boundary (Belford, 1974). The upper parts of the ranges of some upper Oligocene nannofossils such as Reticulofenestra scissura and Sphenolithus ciperoensis overlap with the basal range of G. quadrilobatus primordius in hemipelagic sediments from several areas such as the Bonaparte Gulf Basin. This, plus the occurrence of Globorotalia opima opima indicate that the Zones N.3 and N.4 should be combined into Zone N.3/4, the base of which is defined by the Globigerinoides datum.

That the first appearance (up-sequence) of G. quadrilobatus primordius is diachronous, resulting essentially from its dissolution, is indicated by its limited occurrences in deep oceanic sediments relative to those of the solution-resistant S. ciperoensis. A shallow lysocline combined with a thick lysocline-calcium compensation surface (CCS) zone during the late Oligocene is invoked to account for the disjointed ranges of G. quadrilobatus primordius and S. ciperoensis in deep oceanic sediments and also for their overlap in shallow hemipelagic sediments. Dissolution among the upper Oligocene sediments can be described as "out of phase" i.e. increases in dissolution in deep sediments correspond to decreases in dissolution in shallow sediments. This can be attributed to changes in the thickness of the zone between the lysocline and CCS which maybe a result of cooling; a drop in the temperature of the oceans during the late Oligocene to a minimum of about $4^{o}C$ in high latitudes has been indicated by Savin, Douglas & Stehli (1975).

Perth Basin. The Gingin Chalk has been the subject of a large number of studies. However, these studies notably lacked contributions dealing with nannofossils. The reason is probably because nannofossil biostratigraphy of the Santonian (age of the Gingin Chalk by previous authors) is relatively difficult. Problems hinge on properly illustrating the nannofossils by optical microscopy for successful subsequent identifications and for establishing precisely their relative ranges in a wide space. Analysis of the Gingin Chalk using light microscopy revealed the occurrence of 52 nannofossil species. These are assigned to the proposed Broinsonia furtiva Zone.

Nannofossil evidence supports the conclusion that deposition of the Gingin Chalk was in an epicontinental sea which had a good access to the open ocean.

The Kings Park Formation has also been analysed. Paleocene and Eocene nannofossils were recorded, and a discussion of the status of the formation was given. Preliminary results published in Record 1975/157 concerning the Kings Park Formation were finalized in a manuscript to be published in the "Crespin Commemorative Volume", a BMR Bulletin.

Southwest Pacific. A paper on the "nannofossil biostratigraphy of the southwest Pacific, Deep Sea Drilling Project, Leg 30" has appeared in the Initial reports of the Deep Sea Drilling Project, Vol. 30, pp. 549-598. Also contributions to each site are published in the same volume. A nannofossil biostratigraphic scheme spanning the Late Cretaceous to the Quaternary was used in the study of the five holes drilled during Leg 30, also documentation of the hiatuses detected in the Southwest Pacific region was given.

COMPUTING GROUP

by

K. Long

GEOLOGICAL BRANCH PROGRAMS - NEW ADDITIONS

All working Geological Branch computer (Cyber 76) programs are now held on file (GEOLPROGS) in UPDATE format - on disc for normal access and on magnetic tape for backup. Several new programs, obtained from various sources, have been added to this "GEOLPROGS" file in the last year -

1. CMAS, a program which plots the composition of samples within a stereo pair of CMAS tetrahedra

2. PLANE, which calculates the projections of samples into various compositional planes within the CMAS tetrahedron

3. FAP, a fracture analysis program, which draws rose diagrams and histograms from data digitized from maps and air photographs

4. GXYPLOT, which draws X-Y plots on the line-printer for pairs of variables selected in various combinations from up to 30 variables. Data from different sets may be distinguished by different symbols on the plots

5. NONLIN, which estimates parameters of nonlinear simultaneous equations

6. PROBPLT, a program to plot cumulative frequency curves of classified data with a probability scale on the Y axis

7. SPEAR, which calculates a correlation matrix from supplied data, using Spearman's rank correlation formula.

"GEOLDOCS"

Each of the "GEOLPROGS" programs is documented on punched cards in the BMR standard documentation format. All programs have sections detailing purpose and driving instructions, and some also have example data sets and corresponding example output. This set of documentations will soon be available as BMR Record 1976/82 on microfiche. It is also to be published as a BMR Report on microfiche.

PROJECT INDEXING SYSTEM

The Project Indexing System, a project-based index to geological data collected by the BMR, has been implemented using a computer storage-retrieval system, "INFOL". It is intended in part to replace the Sample Submission Form which was required to be completed by geologists for every sample collected in the field. This form contains such information as latitude and longitude (or grid reference) of the sample site, date of collection, field book reference, age of samples, etc. The Project Indexing System, on the other hand, stores information on where particular items such as rock samples, thin sections, sample locality data, etc, may be found. This information may be accessed via keys such as project name, State, 1:250 000 Sheet areas sampled and trace elements analysed. The indexing is done at the completion of a project.

GEOCHEMICAL MAPPING PROJECT

A system of producing parts of geochemical maps directly by computer has been devised, using pre-existing Cyber 76 programs for plotting localities, with some minor additions for plotting the required geochemical symbols. The BMR's flatbed plotter is used to scribe symbols at the appropriate sample sites on a scribe coat base, and this is then incorporated later into the final geochemical map. The symbol chosen for the Georgetown Project, for which the system has been developed, incorporates 4 different colours, and as 6 maps are to be produced, a large amount of tedious work for draftsmen has been avoided.

GROUNDWATER LEVELS SIMULATION

Work was commenced on the programming of a mathematical model to simulate the groundwater levels between drains at various spacings for the Lanyon groundwater study. The model which has been devised by J. Kellett (Engineering Geology) is based on the one-dimensional heat-flow equation.

25TH INTERNATIONAL GEOLOGICAL CONGRESS

W.J. Perry organized typesetting and printing of the abstracts of the scientific papers, and of the 20 "B" excursion guide books, a task that occupied an increasing amount of time during the period from April to August. The abstracts ran to three volumes totalling 936 pages.

Field excursions were organized and run, and excursion guides written as follows: Georgina Basin (4C) - E.C. Druce, J.H. Shergold; Amadeus Basin (48A) - A.T. Wells; Bowen and Surat Basins (3C) - A.R. Jensen, N.F. Exon (in collaboration with J.C. Anderson and W.H. Koppe of the Geological Survey of Queensland); Lightning Ridge Opal Field (7B) - G.G. Holmes (Geological Survey of New South Wales) and B.R. Senior. J.M. Dickins acted as a guide to a Bowen Basin excursion organized during the Congress.

ESCAP STRATIGRAPHIC ATLAS PROJECT

H.F. Doutch took up an ADAA appointment to the United Nations in Bangkok in September for two years. He is attached to the National Resources Section of ESCAP (Economic and Social Commission for Asia and the Pacific) as stratigrapher in charge of a project to prepare a stratigraphic atlas of the ESCAP region. A. Mond completed draft stratigraphic correlation diagrams of the Carnarvon Basin, in co-operation with Petroleum Exploration Branch, as a contribution to the atlas, before joining the Westmoreland Party early in 1976.

BAAS BECKING GEOBIOLOGICAL RESEARCH LABORATORY

Convener, Operating Committee; A.R. Jensen

Executive Officer: P.A. Trudinger

ORE GENESIS INVESTIGATIONS

GEOCHEMICAL-PETROGRAPHIC INVESTIGATIONS OF ROCKS AROUND BASE METAL SULPHIDE DEPOSITS, SOUTHEASTERN NEW SOUTH WALES

by

I.B. Lambert

STAFF: I.B. Lambert (CSIRO), M.D. Petersen (post-doctoral fellow).

Geochemical and petrological investigations are being undertaken on representative rock samples from diamond-drill holes around base-metal sulphide deposits in the Woodlawn, Captains Flat, and Orange areas in the Lachlan Fold Belt of NSW. In each case the mineralization is closely associated with Middle to Upper Silurian felsic volcanics.

The main aim of these studies is to elucidate details of the nature and distributions of rock types, alteration haloes and geochemical anomalies associated with the deposits, thereby obtaining information which is essential for establishing metallogenetic models and exploration guides.

Woodlawn area

Studies in this area have been completed.

The Woodlawn ore body consists of massive Cu-Pb-Zn sulphide lenses plus stringer and disseminated mineralization. Our investigations have substantiated the general geological picture evolved during complementary studies by Jododex, the NSW Geological Survey and CSIRO Division of Mineralogy (North Ryde), and further elucidated details of rock distributions, alteration minerals and geochemical anomalies in the Woodlawn area.

As outlined in last year's report, there is an extensive aureole of silicification, chloritization, sericitization and stringer mineralization in the felsic volcanics and fine-grained sedimentary rocks around the ore body. Na/Mg ratios increase markedly with distance from the mineralization, K/Na ratios increase sharply close to mineralization and Fe/Mg ratios of chlorites increase away from the ore.

The aureole of chemical and mineralogical anomalies can be divided into several distinct zones.

Zone I occurs in the immediate vicinity of the massive ore. It represents the most intense alteration and may include precipitates from the metal-rich ore-forming solution. It is characterized by abundant stringer mineralization, chlorite schists and cherts, together with altered volcanic and sedimentary rocks. The rock chemistry is dominated by high Mg and Fe values with low SiO_2 in the cherts; the altered volcanics and sediments are chemically intermediate between these extremes. Ca and Na contents of all rocks are very low, as evidenced by the absence of plagioclase, and K is slightly depleted on average.

Zone II surrounds Zone I. It is a relatively extensive zone of less intense hydrothermal alteration, characterized by less common stringer and disseminated mineralization and a virtual absence of felspars (except in some basic rocks). There is widespread silicification of the felsic volcanics, whilst Mg contents are significantly higher than in unaltered felsic volcanics and sediments, and tend to increase towards the ore body. Na and Ca are much depleted, but K contents are slightly high to normal and reflect the abundance of sericitic muscovite.

Zone III, which comprises the volcanic pile to the south of the ore body evidently was not permeated ubiquitously by hydrothermal solutions. It contains patchy development of chlorite-rich rocks and stringer to disseminated base metal and pyrite mineralization. Elsewhere the felsic volcanics tend to be silicified, but they generally contain albitic felspar; sericitic muscovite is the major potash-bearing mineral. The chemical features of the rocks in this zone are therefore highly variable.

Outside these zones there is some silicification of the felsic volcanics and some other minor chemical changes which can be ascribed largely to deuteric alteration and burial diagenesis/metamorphism, rather than to mineralization.

It is considered that sea water descended into the volcanic pile and was heated and chemically modified to a minor degree as it circulated and ascended to the surface, where it gave rise to Zone II alteration by reaction with the volcanics and sediments. Ore formation and Zone I alteration could have occurred relatively rapidly following mixing of this circulating sea water with highly metalliferous solutions. The latter would be analogous to those which form porphyry copper deposits and could have been generated during sub-volcanic magma fractionation and/or by extensive rock leaching at moderate to high temperatures. Explosive volcanic activity offers a feasible means of "tapping" the metalliferous solution and enabling rapid ascent of the resultant mixed solution.

Captains Flat and Orange areas

Assessment of geochemical data for volcanics obtained at various distances from mineralization in the Captains Flat and Orange areas is in progress. Comparison of the data with those from Woodlawn is envisaged.

MINERALIZATION IN THE GOLDEN DYKE FORMATION

by

W.M.B. Roberts, T.H. Donnelly (CSIRO)

STAFF: W.M.B. Roberts, T.H. Donnelly (CSIRO), D.B. Fitzsimmons.

The purpose of this investigation is to establish the genesis of the base-metal mineralization in a portion of the Golden Dyke Formation on the western flank of the Pine Creek Geosyncline.

The investigation has been completed and a paper entitled 'Stable isotope study of base metal deposits in the Golden Dyke Formation' has been prepared for publication.

The Golden Dyke Formation is part of the Lower Proterozoic Goodparla Group of sediments and is hostrock to uranium, gold and base metal deposits. In this study three base metal deposits were selected for isotopic examination: the Mount Bonnie and Browns deposits approximately 150 km and 80 km south, respectively, from Darwin; and the Woodcutters deposit approximately 8 km east of the Browns deposit.

Stable isotopes of sulphur from sulphides separated from both the mineral deposits and unmineralized Goodparla sediments were used to determine the source of sulphur from which each deposit formed, and to carry out temperature studies. Carbon and oxygen isotopes from carbonate and carbonaceous material associated with each of the deposits, and carbonate from the unmineralized Coomalie and Celia Dolomite Formations, were examined to determine the source of carbonate, the chemistry of the fluids and the origin of the hydrothermal solutions associated with each deposit.

Results were obtained which suggested that connate fluids have been involved in the formation of each deposit examined. The Mount Bonnie deposit is shown to have a genesis linked closely with basic intrusives. In contrast the Woodcutters deposit apparently formed at a lower temperature (150^{o}C) and the sulphide, from which the metal sulphides formed, came from an organic-rich carbonate environment. The Browns deposit formed

from a combination of both of these processes. All carbonate examined proved to have a marine origin. When the isotopic evidence is compared with the geological evidence the results show close agreement.

The deposits are located in the same stratigraphic position - the base of the Golden Dyke Formation, near the contact with the Coomalie Dolomite. Because of the importance of this zone for future mineral exploration a subsurface geological map of the Rum Jungle Special Sheet area was completed, data of subsurface geology being obtained by stratigraphic drilling done during the 1973-74 field seasons, and interpretation of geophysical work carried out in the 1974 field season. Further information was derived from BMR and company reports. The map is at present in preparation.

REDBANK COPPER PROSPECT

by

W.M.B. Roberts

STAFF: W.M.B. Roberts, J. Knutson, John Ferguson.

An investigation of the Redbank Copper Prospect commenced in August - the main objective being to determine the source of the copper mineralization in the area. Results of a preliminary study of the petrology and mineralogy of selected cores and hand specimens confirmed that mineralized rocks are heavily altered volcanics and possibly volcanic breccias. The investigation has also shown that what was previously mapped as a volcanic rock underlying the Wollograng Formation is actually dolerite.

GEORGINA BASIN STUDY

by

J. Knutson

The objective of this study is to ascertain the manner in which lead and zinc have been concentrated in carbonate rocks of the Georgina Basin.

Optical and SEM examinations of polished thin sections of Upper Cambrian and Lower Ordovician rocks with anomalously high lead and zinc values were carried out. Sphalerite and galena were observed in some samples and they tend to concentrate

along solution veins. Other anomalous zinc values are associated with iron and manganese oxides although in several other cases the nature of the zinc anomaly is, as yet, undetermined. Lead anomalies are always associated with galena. No lead or zinc have been identified in carbonate minerals.

PRECAMBRIAN MICROFOSSILS

MICROFOSSILS, CHERTS AND ASSOCIATED MINERALIZATION IN THE McARTHUR LEAD-ZINC-SILVER DEPOSIT.

by

D.Z. Oehler and J.H. Oehler

STAFF: D.Z. Oehler, J.H. Oehler, in collaboration with R. Logan (Carpentaria Exploration Company) and N.J.W. Croxford (Mount Isa Mines).

Within the ore-bearing sequence of the H.Y.C. Pyritic Shale Member (Barney Creek Fm.), there are several laterally discontinuous layers of fragmented and globular black chert. These cherts are considered to have developed from colloidal silica which precipitated directly from the water column onto the basin floor. Characteristically, the chert fragments and blebs are rimmed by sphalerite; less commonly they are partly rimmed by galena. Textural studies indicate that sphalerite and galena deposition and chert formation occurred over a prolonged period before final lithification of the sediments. "Colloform" textures in sphalerite associated with these cherts appear to have formed through replacement of radially fibrous, chalcedonic quartz.

The cherts contain a diverse assemblage of microfossils, including filamentous bacteria, unicellular algae, and filamentous algae. Analysis of this biota suggests that the bacteria lived at the bottom of the basin, below the photic zone, and that the algae lived in overlying, near-surface waters. No fossils of sulphate-reducing bacteria have been recognized. There is no palaeontologic evidence to indicate that any of the preserved organisms were capable of concentrating non-ferrous metals, although virtually all the bacterial fossils are pyritized. It appears that the bacteria played an indirect role in formation of this deposit by consuming oxygen during their heterotrophic decomposition of detrital algal material and, thereby, maintaining the anoxic bottom conditions necessary for accumulation and preservation of fine-grained sulphide minerals. Differences between the microbiota of this deposit and those described from other formations in the McArthur Group suggest that microfossils may be used for biostratigraphic zonation of the Group.

MICROFLORA OF THE BALBIRINI DOLOMITE

by

J.H. Oehler and D.Z. Oehler

Optical microscopic analysis of microfossils in the Balbirini Dolomite indicates that the preserved biota was dominated by entophysalidacean and chroococcacean blue-green algae. These organisms grew in stratiform stromatolites in an arid, saline, intertidal to supratidal environment. Spheroidal sporangia are abundant at some localities and probably were planktonic. Gliding filamentous algae are rare in this deposit. Sulphate-reducing bacteria may have produced sulphide that reacted with iron in algal sheaths and eventually formed pyrite granules associated with certain microfossils. There is no convincing evidence for the presence of eukaryotic organisms in this assemblage.

The Balbirini Dolomite is one of the upper formations of the McArthur Group; its microflora has been compared with that described from the Amelia Dolomite, one of the lower formations of the Group, and differences between the two biotas may prove useful for local biostratigraphic correlation.

STABLE ISOTOPE INVESTIGATIONS OF ORE BODIES AND ASSOCIATED ROCKS

SEDIMENTARY ROCKS, NICKEL DEPOSITS AND GOLD DEPOSITS, YILGARN BLOCK, WESTERN AUSTRALIA.

by

T.H. Donnelly and I.B. Lambert

STAFF: T.H. Donnelly, I.B. Lambert and D.Z. Oehler in collaboration with J.A. Hallberg, D.R. Hudson (CSIRO Western Australia), O.A. Bavington (W.M.C.) and L.Y. Golding (University of Melbourne).

The study was designed with the following broad aims in mind:

i) to form a basis for future detailed studies in areas of specific interest,

ii) to assess the likely sources of sulphide, carbonate and reduced carbon in these ancient rocks, and

iii) to look for evidence indicating the time of evolution of living organisms, and the subsequent time at which bacterial sulphate reduction became an important process in the area.

Isotopic compositions of sulphur, carbon and oxygen have been determined for constituents from a total of 105 samples of sedimentary rocks, nickel ores, and gold ores from the Archaean Yilgarn Block.

Sulphides in the bulk of the sedimentary rocks have ^{34}S values close to $0^{o}/oo$ and appear to have precipitated from solutions which incorporated magmatic sulphur (either juvenile or leached from older rocks). There is no evidence for widespread bacterial or abiological sulphate reduction.

^{34}S values of sulphides in the Ni deposits and associated mafic/ultramafic igneous rocks are within the magmatic range. Coexisting sulphide minerals in these deposits generally have similar ^{34}S values. The Ni deposits appear to fall into two isotope groups. The small, high-grade deposits of the Kambalda-Nepean-Scotia type have small positive ^{34}S values, and the large, low to medium grade dunite-associated deposits of the Mount Keith-Perseverance type have small negative ^{34}S values.

Sulphides in the Kalgoorlie gold ores are enriched in ^{32}S relative to those in their host dolerite, supporting an epigenetic origin for the gold under moderately high CO_2 conditions.

The bulk of the kerogen (reduced carbon) in the sediments appears to have formed syngenetically. It could be biogenic, with loss of light carbon by thermal degradation in some cases. Alternatively, it could have formed wholly or partly from hydrothermal exhalations containing reduced carbon species of deep-seated origin.

In the great bulk of the sediments, carbonates are predominantly in epigenetic, sulphide-bearing veinlets. In many cases, their ^{13}C values are consistent with precipitation from hydrothermal solutions containing magmatically derived CO_2. Anomalously light carbonates that occur in some sediment samples have possibly incorporated isotopically light carbon derived from magmatic methane and/or pre-existing kerogen sources. Only two sediment samples in this study contain carbonate with ^{13}C values in the range for marine carbonates. Talc-carbonate altered ultramafic igneous rocks have ^{13}C values consistent with influx of magmatically derived CO_2.

GOLD DEPOSITS IN BANDED IRON-FORMATION, RHODESIA

by

T.H. Donnelly and I.B. Lambert

STAFF: T.H. Donnelly (CSIRO), I.B. Lambert (CSIRO), in collaboration with R.E.P. Fripp (University of Witwatersrand).

Isotopic data on sulphides from Rhodesian Archaean banded iron-formation support geological and geochemical evidence for a volcanogenic origin, with the sulphur in the hydrothermal mineralizing fluids being of magmatic derivation. There is no evidence that these fluids incorporated isotopically heavy sulphate, or that bacterial and/or abiological sulphate reduction contributed significant amounts of sulphide.

LAISVALL Pb-Zn ORE DEPOSIT, SWEDEN

by

T.H. Donnelly

STAFF: T.H. Donnelly (CSIRO), in collaboration with D.T. Rickard and M.Y. Willden (University of Stockholm).

This study was carried out to assess the origin of sulphur and carbon in this deposit.

The stable isotope ratios of S, C and O are in accord with a model in which the sulphide is derived from abiological reduction of deeply circulating Lower Palaeozoic seawater-sulphate. The organic reduction process could be responsible for the light carbon in the dissolved CO_2. It has been reported that abiological sulphate reduction can occur in the presence of organic material and Fe ion at $200^{\circ}C$, a temperature not incompatible with that indicated from fluid inclusions and oxygen isotopic studies of the Laisvall ore. These virtually sulphate-free solutions, similar to oil-field brines, moved up-dip towards the Laisvall area where the ore minerals were precipitated at shallow levels during mixing with local groundwaters. The local groundwaters were sulphate-containing, the sulphate being derived from pyrite oxidation in the overlying Alum shales, and barium in the hydrothermal solutions was precipitated as barite.

ISOTOPIC COMPOSITION OF CARBON AND OXYGEN IN ARCHAEAN SEDIMENTS FROM ISUA, GREENLAND

by

D.Z. Oehler

STAFF: D.Z. Oehler in collaboration with J.W. Smith (CSIRO, Sydney).

The purpose of this study was to look for evidence of life in five extremely old sedimentary rocks (ca. 3.76×10^9 years old) from the Isua province of Greenland. Reduced carbon isolated from three of these rocks is isotopically heavier ($^{13}C_{PDB}$ from -11.3 to -17.4 $^{o}/oo$) than most biogenic kerogen in younger rocks. This reduced carbon appears to be syngenetic with the host sediments, but it is not known whether its isotopic composition is primary or reflects metamorphic alteration. Trace amounts of lighter reduced carbon ($^{13}C_{PDB}$ from -21.4 to -26.9 $^{o}/oo$) occur in the other two samples. This material is isotopically comparable to younger, biogenic carbon, but its extremely low concentration suggests that it may not be syngenetic with the host rocks.

Carbonates from the same 5 samples have $^{13}C_{PDB}$ values ranging from -1.4 to -7.7 $^{o}/oo$ and $^{18}O_{SMOW}$ values ranging from +7.4 to +17.0 $^{o}/oo$. The ^{18}O values are similar to those reported from other early Precambrian carbonates which, as a group, are enriched in O^{16} compared to carbonates of younger age. This may reflect a higher temperature, or an ocean relatively enriched in O^{16}, in the early Precambrian.

EXPERIMENTAL STUDIES INVOLVING SULPHUR

EXPERIMENTAL STABLE SULPHUR ISOTOPE STUDIES

by

L.A. Chambers and P.A. Trudinger

STAFF: P.A. Trudinger, L.A. Chambers, A. Rutter (until March) and J. Gadsby.

Sulphur pathway and anaerobic chemical reactions

Experiments have been undertaken to evaluate the importance of intermediate oxidation states of sulphur in the cycling of this element between sulphate (+6) and sulphide (-2).

Thiosulphate, which is often a significant component of natural sulfureta in sedimentary basins, has been shown to accumulate during sulphite reduction by both sulphate and non sulphate-reducing bacteria. Evidence to date suggests that it is most likely formed by an anaerobic chemical reaction between sulphide and sulphite. This finding has important implications with respect to the biogeochemical cycling of sulphur and to the interpretation of sulphur isotopic data in natural environments.

Attempts will now be made to determine the relative contributions of biological and chemical reactions to the sulphur patterns in modern sediments.

ABIOLOGICAL REDUCTION OF SULPHATE

by

L.A. Chambers and P.A. Trudinger

STAFF: L.A. Chambers, P.A. Trudinger, J. Gadsby, in collaboration with J.W. Smith (CSIRO, Sydney).

Sulphate reduction at temperatures which preclude bacterial activity is an important facet of some hydrothermal models, and has placed emphasis on the reactions between sulphur compounds and organic material. In experiments with organic material, sulphur, ^{35}S-sulphate and water at 220°C for 14 days, labelled sulphide was produced. However, in the absence of added elemental sulphur, the total amount of H_2S produced was only one quarter of the sulphur content of the organic material, and the specific activity indicated that approximately 10% had originated from sulphate. Addition of elemental sulphur strongly stimulated sulphide production, but in no instance did the amount produced exceed the S^o in the system. This suggests that the controlling reaction could be the hydrolysis of sulphur and that exchange between sulphate and sulphide produces small amounts of labelled sulphide.

CHARACTERISATION OF REDOX PIGMENTS OF SULPHATE-REDUCING BACTERIA

by

H.E. Jones

STAFF: H.E. Jones (CSIRO), in collaboration with M. Bruschi (C.N.R.S. Marseille).

As the final stage of a study on redox pigments of sulphate-reducing bacteria, of interest because of their likely relevance to the pathway of reduction of sulphite to sulphide,

three cytochromes and one ferredoxin from Desulfovibrio africanus were partly characterised. Their chemical and physical characters have been compared with those of similar pigments from other representatives of this group of bacteria.

STUDIES RELATED TO MODERN ENVIRONMENTS

SULPHATE REDUCTION IN AQUATIC ENVIRONMENTS

by

G.W. Skyring

STAFF: G.W. Skyring (CSIRO), in collaboration with W.J. Wiebe (University of Georgia, U.S.A.).

Publications from the Marine Institute, University of Georgia have made available a sizable array of data on the physical, chemical and biological properties of a broad band of salt marshes along the southeast coast of the U.S.A. Cores taken from this region have been reported to show considerably reduced areas with an odour of H_2S, indicative of active sulphate reduction. A study of sulphate reduction in this region has therefore been commenced and, because the region has been considerably characterised, factors which affect the rate of sulphate reduction may be more readily delineated.

Techniques are being designed and tested for estimating the rates of diffusion of sulphate in the sediments, for rapid recognition of the in situ presence of bacterial sulphate reduction and for assay of its rate.

SULPHUR CYCLING IN THE BALTIC SEA

by

L.A. Chembers

STAFF: L.A. Chambers, P.A. Trudinger, J.W. Smith (CSIRO, Sydney), in collaboration with L.E. Bagander and R.O. Hallberg (University of Stockholm).

As part of the Laboratory's investigations on the biogeochemistry of modern sedimentary environments a collaborative study on sulphur transformations in the Baltic Sea is in progress.

A succession of bacterial flora, including sulphate-reducing and sulphur-oxidising organisms has been observed in anaerobic boxes used by Hallberg for in situ studies of the

Baltic sediments and water-column. Chemical analysis of sulphur species suggests that this succession could be associated with phases of an isolated simple sulphur cycle. Stable sulphur isotope changes are now being studied in two "Hallberg" boxes positioned in May 1976. Initial results show sulphate reduction and an associated fractionation of -20o/oo in the produced sulphide. The experiment is expected to continue until February-March 1977.

GEOMICROBIOLOGY OF MODERN SEDIMENTARY ENVIRONMENTS

by

H.E. Jones

In view of the laboratory's future studies in Spencer Gulf, South Australia, a review of recent information of relevance to the geomicrobiology of modern sedimentary environments has been made. The review is mainly concerned with methodology, both in situ and in the laboratory, and is divided into six main sections:

(1) A broad coverage of microbial reactions considered to have geobiological significance both in marine and freshwater situations;

(2) Sampling procedures and sources of sample contamination;

(3) In situ investigations and laboratory systems;

(4) isolation, enumeration and identification of mico-organisms;

(5)Biomass and productivity studies; and

(6) Estimation of rates of microbial processes.

Examples of investigations employing different techniques are included and the effectiveness and universality of application of the approach and the problems inherent in the techniques are discussed.

OVERSEAS VISITS

P.A. Trudinger

Dr. Trudinger spent three months at the Department of Chemistry, University of Southern California at San Diego and took part in a program on the comparative biochemistry of autotropic energy metabolism in procaryotes. The program is designed to gain insight into the evolution of this biogeochemically important group of organisms and Dr. Trudinger studied a species of Thiobacillus which is involved in the oxidation of inorganic sulphide and sulphur.

A novel c-type cytochrome, a porphyrin-derived component of the respiratory chain, was isolated, purified and characterized. Further work to be undertaken by colleagues at San Diego will be aimed at determining the amino-acid sequence of the pigment and the "relatedness", or otherwise, of the cytochrome to analogous pigments in other genera of microorganisms.

I.B. Lambert

Dr. Lambert spent most of May 1976 in Canada at the invitation of Cominco Ltd and visited the Sullivan mine region, the Noranda mining field and the Geological Survey of Canada at Ottawa. He attended a workshop on "Proterozoic stratiform base metal ores" and presented:

(i) an assessment of geochemical and geobiological evolution in the Precambrian and their bearing on the formation of large stratiform ore deposits, and

(ii) a comparison of the features of the McArthur Zn-Pb-Ag deposit with those of the Sullivan deposit.

L.A. Chambers and T.H. Donnelly - International Conference on Stable Isotopes, D.S.I.R., Lower Hutt, New Zealand, August 4th-6th, 1976.

Valuable discussions were held with participants at the congress on sulphur and carbon isotope distribution in contemporaneous environments and ancient sulphide deposits, and related hydrothermal and experimental studies relevant to current and proposed investigations in the laboratory. T.H. Donnelly presented a paper entitled "A reconnaissance study of stable isotope ratios in Archaean rocks from Western Australia".

METALLIFEROUS SECTION

Head of Section: W.B. Dallwitz

GEOLOGICAL INVESTIGATIONS IN NORTHERN TERRITORY, WESTERN AUSTRALIA, AND ANTARCTICA

Supervising Geologist: R.G. Dodson

ARUNTA BLOCK

by

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

STAFF: R.D. Shaw (overseas for entire year), A.J. Stewart, R.G. Warren, A.P. Langworthy, L.A. Offe, L.P. Black (part-time) and A.Y. Glikson (part-time; B.E. Hobbs (Monash University) is associated with the project.

The objectives of the Arunta project are:

1. To gather fundamental geological data on the Arunta Block, in order to determine its geological make-up and evolution and its place in the overall geological framework of Australia, and to make these data and conclusions available to assist mineral exploration.

2. To identify, study, and assess the mineral resources of the Arunta Block.

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

1. Preparation of a summary report and map (Fig. M2) on minerals of potential economic interest in the Arunta Block; this topic formed the subject of a lecture at the annual BMR Symposium;

2. Commencement of a geochemical survey of a copper and tungsten-bearing area in the far east of the Block;

3. The broad subdivision of the Arunta Block into three major stratigraphic groups, described in last year's summary, has proved to be of considerable use and has been retained. Figure M3 is a generalized geological map of the Arunta Block showing these divisions and granite, and incorporates the results of BMR work from 1956-76. The tentative correlation of the second and third divisions with units in The Granites-Tanami and Tennant Creek Blocks has been substantially confirmed.

4. Co-operation continued with the Sedimentary Section in production of the Mount Solitaire and Lander River 1:250 000 Sheets.

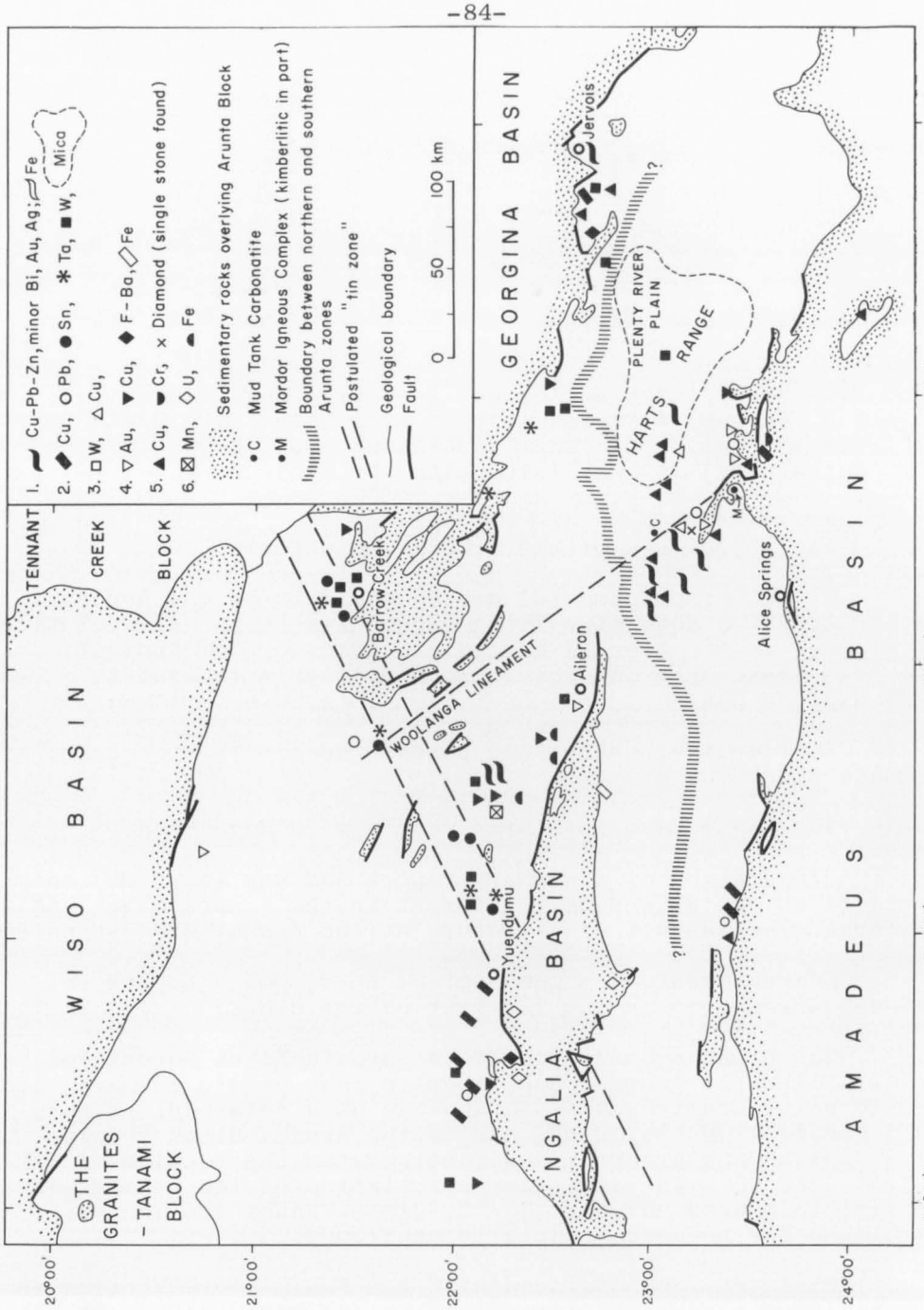


Fig. M2. Distribution of mineral occurrences in Arunta Block; Category 1 - stratabound; 2 - pegmatic; 3 - metasomatic; 4 - hydrothermal; 5 - magmatic segregations; 6 - weathering. Orientation of elongate metallogenic symbols has no structural significance.

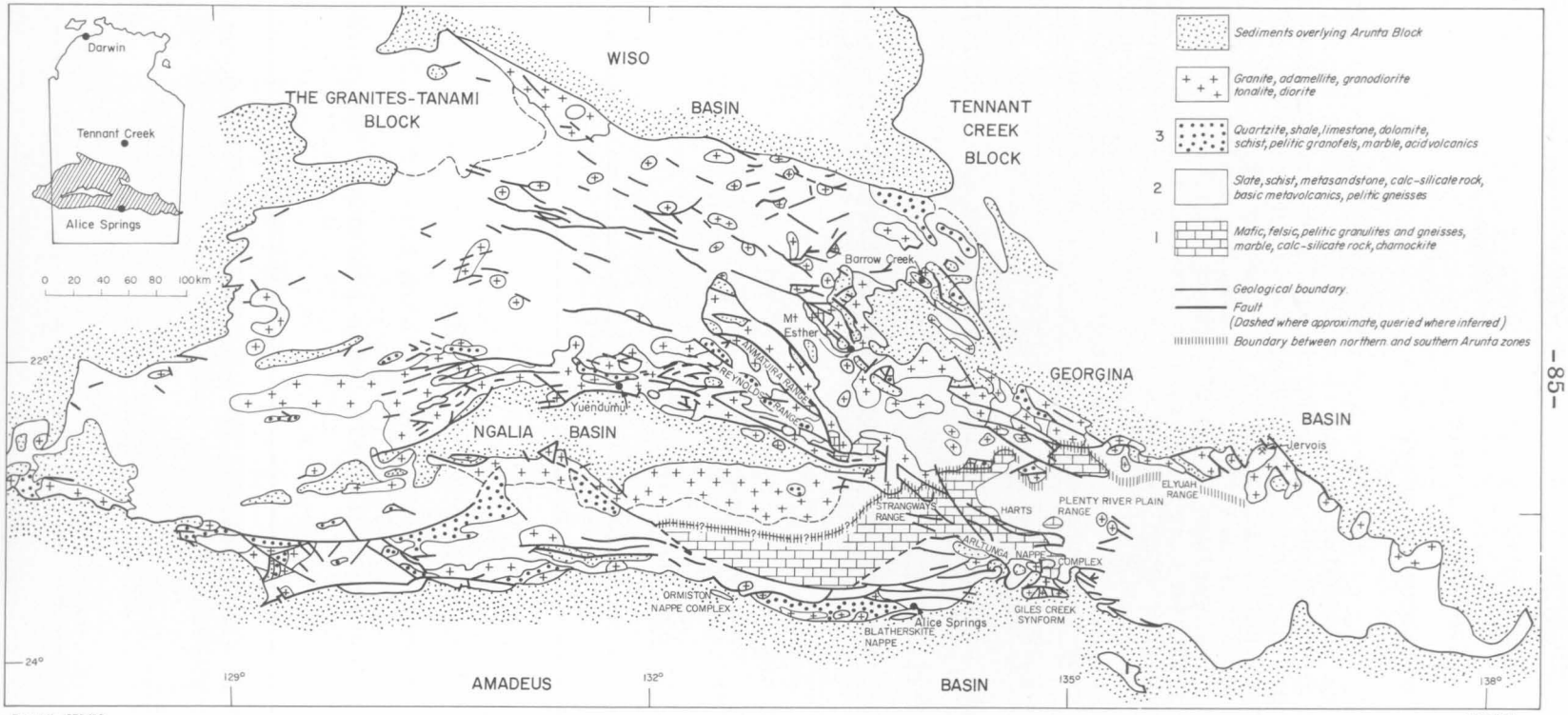


Fig M3 Generalised geological map of Arunta Block, showing major stratigraphic subdivisions (1–3) and granite
Inset map shows location of Arunta Block in southern part of Northern Territory

Fig. M3. Generalised geological map of Arunta Block, showing major stratigraphic subdivisions (1-3) and granite. Inset map shows location of Arunta Block in southern part of Northern Territory.

FIELD WORK by Stewart and Offe

ALICE SPRINGS 1:250 000 SHEET AREA

Writing of the data Record 'Geological report on 1:100 000 scale mapping of the southeastern Arunta Block, Alice Springs 1:250 000 Sheet area, Northern Territory' was continued by Langworthy and Warren, including formal descriptions of stratigraphic units, and chapters on geochemistry, metamorphism, and results of scout drilling. Preparation of the metamorphic map of the Alice Springs 1:250 000 Sheet area began, but data-coding difficulties have temporarily defered it. The draft manuscript 'The Mordor Complex: a highly differentiated potassic intrusion with kimberlitic affinities in central Australia', by Langworthy and Black, was extensively reviewed and revised, and is almost ready for submission for outside publication.

Laughlen 1:100 000 Sheet Area

The Preliminary Edition was issued in October 1976.

Burt 1:100 000 Sheet Area

Drafting of the Preliminary Edition was completed, and at the end of the year the map was being readied for despatch to the printer.

Alice Springs 1:100 000 Sheet Area

Drafting of the Preliminary Edition is well advanced.

Undoolya 1:100 000 Sheet Area

Preparation of photo-overlays was completed, and photo-scale compilation preparatory to drafting of the Preliminary Edition began in October 1976.

HERMANNSBURG 1:250 000 SHEET AREA

MacDonnell Ranges 1:100 000 Sheet Area

Basement rocks in the northern half of the Sheet area were mapped during the 1976 field season. The field work is now complete and photo-overlays are being prepared. The rocks of the northern area consist of deformed gneiss, migmatized gneiss, leucocratic gneiss, porphyroblastic gneiss, and amphibolite. The deformed gneiss crops out along the northern flank of the MacDonnell Ranges and is an extension of the west-trending Redbank Zone mapped in the adjoining Hermannsburg 1:100 000 Sheet area to the west.

ALCOOTA 1:250 000 SHEET AREA

The draft report 'Geology of the Alcoota 1:250 000 Sheet area', by Shaw, Warren, Senior, and Yeates, is with the Editors.

NAPPERBY 1:250 000 SHEET AREA

Aileron 1:100 000 Sheet Area

Clean-up work to reconcile different interpretations of the geology of the Aileron Sheet area was completed during the 1976 field season. The rare mineral kornerupine ($Mg_3Al_6(Si,B)_5O_{21}(OH)$) was identified by X-ray diffraction in metapelite granulite 21 km northwest of Aileron; the mineral has been recorded only once before in Australia, from the Strangways Range in the Arunta Block by Woodford and Wilson (N. Jb. Miner. Mh., 1976, 1, 15-35).

Reynolds Range and Tea Tree 1:100 000 Sheet areas

Preliminary Editions of these Sheets were printed and distributed in January 1976.

MOUNT PEAKE 1:250 000 SHEET AREA

A dark-green specimen of suspected chrysoprase, which fills a veinlet in granite, 1 km west of the abandoned 'Mount Esther' homestead in the southeast of the Sheet area, was identified by petrographic, X-ray diffraction, and electron probe analyses as a chromite-fuchsite-quartz rock. The chromite contains about 30% Cr_2O_3, and the fuchsite (chromium mica) about 4% Cr_2O_3. The rock as a whole contains 1-2% Cr, 1.7% Fe, 0.0131% Mn, 0.01-0.005% V, 0.0019% Li, 0.0004% Cu, 0.0003% Ni, minor amounts of Ti and Ba, and a trace of Zr. The occurrence of such a chromium-rich rock in granite is something of a puzzle; analysis is continuing.

The First Edition of the Mount Peake 1:250 000 Sheet is ready for contract drafting and the Explanatory Notes are with the Editors.

MOUNT THEO 1:250 000 SHEET AREA

Several localities in the west of the Sheet area, that were not visited during the 1972 helicopter survey, were visited during 1976; the ridge 34 km due west of 'Chilla Well' homestead, shown as pC on the 1:250 000 Preliminary and First Editions, is a fine-grained metaquartzite similar to those in The Granites-Tanami Block of the neighbouring Highland Rocks and Mount Solitaire 1:250 000 Sheet areas.

The First Edition of the Mount Theo 1:250 000 Sheet is in the final stage of printing and the Explanatory Notes are also with the printer.

MOUNT SOLITAIRE 1:250 000 SHEET AREA

Thin-section examination, author's corrections to the Preliminary Edition, and writing of the basement rock sections for the Explanatory Notes were completed, and the Notes and map are with the Map Editing Section ready for editing for First Edition.

LANDER RIVER 1:250 000 SHEET AREA

Preparation of the Explanatory Notes and author's corrections to the Preliminary Edition are in progress.

INVESTIGATION OF THE MINERAL PROSPECTS by Stewart and Warren

Edwards Creek geochemical survey

The Edwards Creek prospect, in the northern part of the Alice Springs 1:250 000 Sheet area (Fig. M2) is an unexploited stratiform occurrence of copper, lead, and zinc in impure marble and Mg-Al granofels. Surface grades range up to 3.6 percent Cu, 4.5 percent Zn, and 4.7 percent Pb. Warren collected soil and stream-sediment samples from the vicinity of the prospect in 1975, as an orientation survey to assist in designing large-scale geochemical prospecting programs for similar prospects elsewhere in the area. The samples were sieved and the -80 fraction analysed for copper, lead, and zinc. The results indicate that the soil dispersion halo around the prospect is about 100 m wide, and that anomalous values for copper, lead, and zinc persist downstream for only about 500 m from the prospect.

A draft report, 'Geochemical sampling adjacent to the Edwards Creek prospect, Arunta Block, central Australia' (Record 1976/68), by Warren on the results of the survey is being prepared.

Metalliferous studies in Huckitta 1:250 000 Sheet area

During the last five years several copper, tungsten, and fluorite prospects have been found in the southern part of the Huckitta 1:250 000 Sheet area, in the far east of the Arunta Block, whereas little was found elsewhere in the Block.

Results of company investigations in the Huckitta area indicate that the copper lodes are mostly of the pegmatite or quartz vein type, and are related to nearby granite. Copper in an amphibolitic host rock is probably endogenic. The tungsten

lodes are found in calc-silicate rock within a few tens of metres of granite or pegmatite, and so are regarded as metasomatic replacements of magmatic origin. The fluorite lodes are found only within 1 km of outliers of Upper Proterozoic sedimentary rocks and some of the fluorite veins intrude the lowest unit of the sedimentary sequence.

Elsewhere in the Arunta Block, copper lodes of the pegmatite-quartz vein type are present north of Yuendumu in the northwest of the Block (Fig. M2) and have been mined in the past. Amphibolite bodies are abundant in the Harts Range in the southeast of the Block (Fig. M2), and copper is known in many of them but in uneconomic amount. Calc-silicate rocks and tungsten-bearing granites are also known throughout the northwest of the Block, but are not everywhere in proximity to one another; geological mapping of this region is not yet complete. Fluorite is known to occur at one locality on the northern margin of the Late Proterozoic-Palaeozoic Ngalia Basin, 55 km west of Yuendumu (Fig. M2), but small fluorite veins also intrude granite well away from sedimentary outliers, e.g. in the Anmatjira Range (Fig. M2).

Warren began geological and geochemical investigations of two known mineral prospects to try to ascertain suitable exploration methods which would locate undiscovered mineral occurrences in this environment. At the Marrakesh tungsten prospect, stream-sediment samples were collected at 100 m intervals downstream from the prospect for 1200 m, then at stream junctions for a further 4000 m. A similar stream-sediment survey was carried out at the Petra copper prospect to compare it with the Edwards Creek base-metal prospect (described above). Samples collected during 1976 are being analysed.

Warren extracted data from open-file company reports held at Mines Branch, Darwin, covering the Arunta Block for the period 1972-76, for inclusion in forthcoming BMR data Records. The most important finds recorded in the reports are an ultramafic intrusion containing chromite, in the northeast of the Quartz 1:100 000 Sheet area, and a concentration of heavy minerals, notably cassiterite, wolframite, and tantalite, in the northwest of the Tea Tree 1:100 000 Sheet area, near the centre of the Block.

ISOTOPIC DATING

Black continued isotopic analysis of samples collected during previous years, and results for this year are presented in the report for the Laboratories Subsection in this Summary.

MISCELLANEOUS ACTIVITIES, by Stewart

25th International Geological Congress

During the 1976 field season, Stewart helped with the pre-Congress Tour 48A of the Amadeus Basin, under the leadership of A.T. Wells, and Stewart, Offe, and Langworthy were guides on the post-Congress Tour 47C of the Arunta Block, under the leadership of R.G. Dodson. After Tour 47C finished in Tennant Creek a reconnaissance traverse was made through the southern part of the Tennant Creek Block and the northern part of the Arunta Block to compare the two regions. As foreshadowed by Shaw and Stewart (in 'Economic Geology of Australia and Papua New Guinea', Aust. Inst. Min. Metall. Monogr. Ser. 5, 437-442, 1975), the Warramunga Group of the Tennant Creek Block is lithologically identical with the Lander Rock Beds of the Arunta Block, and the orthoquartzite and coarse quartz sandstone of the Hatches Creek Group (5500 m thick), which unconformably overlie the Warramunga Group, are lithologically very similar to, though thicker than, the Mount Thomas Quartzite (850 m thick) which unconformably overlies the Lander Rock Beds.

Visit to Broken Hill

Stewart visited the Willyama Block in the Broken Hill area for a 3-day field trip with K.R. Walker, G.M. Derrick, and R.J. Hill, conducted by the Broken Hill staff of the Geological Survey of New South Wales. The trip revealed certain similarities between the Arunta and Willyama Blocks: the 'sillimanite gneiss' of the Broken Hill Mine Sequence is lithologically similar to both the Lander Rock Beds and Mount Stafford Beds of the Arunta Block, and the Potosi Gneiss of the Mine Sequence is very similar to the Irindina Gneiss of the Arunta Block.

PINE CREEK GEOSYNCLINE

by

C.E. Prichard

DARWIN OFFICE

STAFF: C.E. Prichard, P.H. Fuchs, P.R. Lachlan

The year has again been a difficult period for the Darwin Office. Few of the original pre-Cyclone Tracy staff remain; neither the office nor the store/workshop have been repaired since the cyclone.

The Drawing Office resumed operations early during the year. The Cahill 1:100 000 Preliminary has been completed and is being edited. Gilruth Sheet was compiled at 1:50 000 and drafting of the 1:100 000 Preliminary is nearly completed. The southern half of Howship Sheet has been compiled at 1:50 000 and compilation of Kapalga Sheet is in progress.

There has been steady use of the reference facility and a regular demand for geological maps, an average of fifty per month being sold.

Manton Seismic Station has been maintained in operation throughout the year with only minor loss of record.

ALLIGATOR RIVERS PROJECT

by

R.S. Needham and P.G. Stuart-Smith

STAFF: R.S. Needham, P.G. Stuart-Smith, M. Roarty (N.T. Mines Branch, from 30/8/76).

The objectives of this project are:

1) to gain a more detailed understanding of the geology of the Alligator Rivers area;

2) to contribute to the interpretation of the Pine Creek Geosyncline as a whole;

3) to indicate the controls and distribution, and the probable modes of emplacement of uranium mineralization in the area and its relation to mineralization in the Rum Jungle Field, thereby assisting mineral exploration in the region;

4) to prepare and publish eleven 1:100 000-scale geological maps of the area and a second edition of the Alligator River 1:250 000 Sheet.

Field work commenced in 1971 and eleven sheets have been covered; progress reports have been presented annually as BMR Records and a Bulletin synthesizing the geology of the Alligator Rivers Uranium Field is being written. During 1976 emphasis has been on preparation of reports describing 1974-1975 drilling, preparation of 1:100 000 scale preliminary geological maps, and writing of a paper describing a new stratigraphic unit (the Cahill Formation) which is host to uranium mineralization in the Alligator Rivers area. Field mapping was extended to the northwest part of the Mundogie Sheet area, and drilling continued in the Kapalga Sheet area.

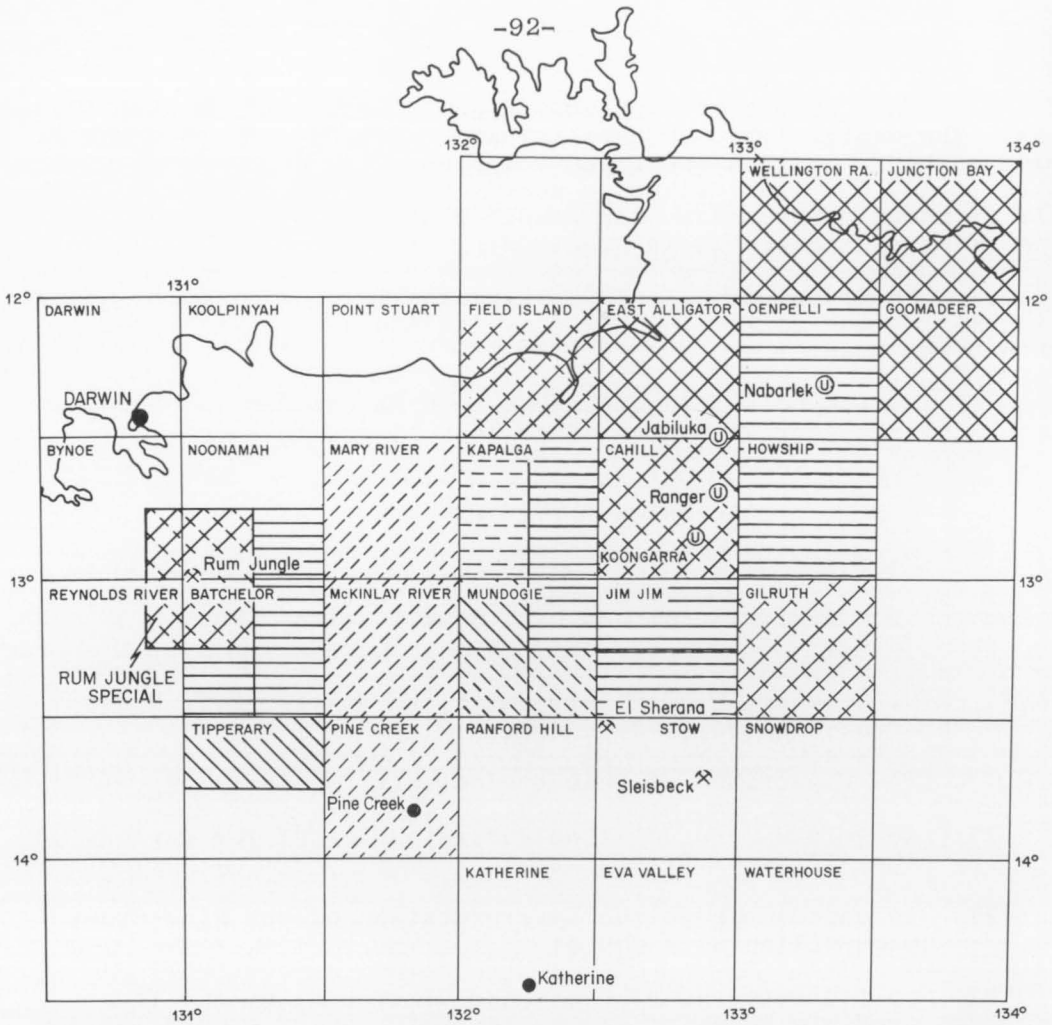


Fig. M4. Progress of geological mapping and index to 1:100 000 Sheet areas, Pine Creek Geosyncline Project.

The forward program of the project was reappraised during the year. A five-year program is now being followed where emphasis is to study a strip joining the Alligator Rivers and Rum Jungle uranium fields, enabling reappraisal of the stratigraphy of the central part of the Pine Creek Geosyncline. The region to be covered are the Mundogie, McKinley River, Mary River, and Pine Creek Sheet areas. The Alligator River and the Rum Jungle parties will combine to carry out this program.

REPORTING

Progress of map production is shown in the frontispiece maps. The Goomadeer, Junction Bay, and Wellington Range 1:100 000 preliminary maps were issued during the year and all the geologists compilations for the eleven 1:100 000 scale Sheet areas comprising the Alligator Rivers Uranium Field is complete apart from some minor checking. Records describing field work in the Oenpelli and Jim Jim regions, and drilling during 1972-3, were issued. A Record describing 1974 drilling results, and a paper describing the Cahill Formation, are in press. Public lectures describing the Cahill Formation were presented at the BMR Symposium and at the 25th IGC.

THE CAHILL FORMATION

All the uranium deposits of the Alligator Rivers Uranium Field are strata-bound within the Cahill Formation (Fig. M4). Three of the four economic deposits are more or less conformable within a lower member near the base of the formation which contains carbonate and carbonaceous rocks. The formation forms a poorly exposed but continuous folded belt, 5 km or more wide, over an area of about 15 000 km^2. Exposure is sparse and the rocks are generally deeply weathered, so knowledge of the stratigraphy of the unit is based largely on the results of shallow stratigraphic drilling carried out by BMR in 1974 (Fig. M4).

Quartzo-feldspathic and micaceous metasediments metamorphosed to the amphibolite grade (staurolite-almandine subfacies) are the dominant rock types in the Cahill Formation.

Carbonate-carbonaceous rocks of the lower member were probably deposited under shallow near-shore shelf conditions, along with considerable admixed terrigenous material. Feldspathic quartzite and schist of the upper part of the formation represent a period of transgression over the shelf.

The unit appears to unconformably overlie the Archaean-Lower Proterozoic granite-gneiss-migmatite Nanambu Complex and the Lower Proterozoic psammo-pelitic Mount Partridge Formation, and is overlain, in places unconformably, by the Fisher Creek

Siltstone. It grades into the migmatite-gneiss-granite terrain of the Nimbuwah Complex in the northeast. The formation is a time, and in part a facies equivalent of, the Koolpin Formation (host to uranium mineralization in the South Alligator Valley uranium field) to the south, and, in places, was separated from it during deposition by a basement high of Mount Partridge Formation. The similarity between the Cahill and Koolpin Formations was realized for a number of years and the Cahill Formation rocks were referred to informally as 'Koolpin Formation equivalent'. The Cahill Formation is clearly distinguished from the Koolpin Formation by the essential presence of feldspar and quartz in most of its constituent rock types.

Uranium was probably concentrated under local reducing conditions within the carbonate shelf. Subsequent concentration and reconstitution took place a number of times, the main period being during 1800 m.y.-old regional metamorphism and deformation. Uranium only moved away from the carbonate-carbonaceous sequence under high temperature and pressure conditions, such as during the formation of the Nimbuwah Complex where the metal was relocated in favourable low-pressure structures.

The metamorphic grade of the Cahill Formation is mostly staurolite-almandine subfacies of the amphibolite facies. Retrograde metamorphism has chloritized ferromagnesian minerals and sericitized feldspars. Garnet, biotite, and amphibole are commonly partly or completely altered to chlorite, and chloritized haloes commonly surrounded small quartz veins. Ferromagnesian metasomatism of the Lower Proterozoic metasediments is most pronounced in the lower member of the Cahill Formation, where rocks are depleted in Na and enriched in Mg, and chlorite has replaced feldspar in feldspathic quartzite to give rise to quartz-chlorite schist. Chloritization is particularly intense in some sheared and brecciated zones, the lower and upper boundaries of the Cahill Formation, indicating that stratigraphic and structural breaks provided pathways for Fe and Mg-rich fluids. Hematitization associated with chloritization is widespread, particularly in the mineralized areas.

Study of cores of Cahill Formation and Fisher Creek Siltstone rocks indicate that the Lower Proterozoic metasediments have undergone at least four phases of deformation, probably all related to the 1800 m.y.-old period of deformation and metamorphism.

Mineralogical and textural banding form the oldest preserved foliation (S_o), and are probably original bedding. S_1 is produced by the parallel growth and alignment of phyllosilicates at a shallow angle (less than 10^o) to S_o. The two foliations are rarely preserved in mica schist but are dominant features of quartzo-feldspathic schist. Intense isoclinal folding transposed S_o and S_1, and, with recrystallization of the

phyllosilicates, produced the dominant schistosity (S_2). Relict isoclinal fold noses are preserved in the more competent quartz-rich bands. Almandine and magnetite porphyroblasts show deformed, rotational, and cross-cutting textures indicating their development before, during, and after this phase of deformation. S_3 - axial plane to tight, angular, and rarely isoclinal folds - was produced by recrystallization of phyllosilicates and development of a crenulation cleavage, which rarely transposed older foliations. Large unstrained mica and idiomorphic kyanite and staurolite porphyroblasts cut the S_3 foliation and indicate a probable temperature increase (widespread granite intrusion?) associated with hydrostatic pressure after the development of S_3. These minerals deflect a later set of poorly developed kinks (S_4) that are not related to major recrystallization or folding. The degree of apparent deformation ranges substantially over small areas, but typically increases towards the Nimbuwah Complex.

MUNDOGIE SHEET AREA

The northwestern quarter of the Mundogie Sheet area was mapped during 1976. The outcrop geology shown on the Mount Evelyn 1:250 000-scale map requires little alteration with the exception of the Stag Creek Volcanics - exposures are more extensive than shown on previous maps. A major unconformity, interpreted on aerial photographs between the Coirwong Greywacke and the Masson Formation, was confirmed. This confirms a previously suspected correlation between the Coirwong Greywacke and all or part of the Mount Partridge Formation. Both units unconformably overlie the Masson Formation and the Stag Creek Volcanics (the latter now regarded as a member of the Masson Formation, at or near the top of the formation), and underlie the Koolpin Formation.

The Koolpin Formation is divisible into two units. The lower part forma s northwest-trending east-dipping belt of ferruginized siltstone with lenses of massive and brecciated silicified dolomite; the Gerowie Chert crops out as narrow continuous ridges towards the top of the sequence. Coarse-grained Zamu Complex dolerite with chilled margins forms extensive sills about 200 m thick in the sequence and is folded with the sediments about subhorizontal fold axes. The upper part of the formation forms a broad north-plunging syncline of massive chert-banded hematitic siltstone between the West and South Alligator Rivers (the Kapalga Syncline). The siltstone forms prominent arcuate ridges, in contrast to the interspersed low rubbly outcrops of Zamu Complex dolerite; carbonaceous shale has been intersected in drill holes by Noranda (Aust.) Ltd between the siltstone ridges and is continuous with carbonaceous shale of the Koolpin Formation detected by BMR geophysics and drilling in the Kapalga Sheet area during 1975. A discontinuous sandy silicified dolomitic breccia crops out at the base of this sequence. The

syncline is extensively modified by numerous northwest-trending faults and associated drag folds, which account for an apparent thickening towards the base.

The relationship between the upper and lower parts of the Koolpin Formation is not clear. Both parts appear to unconformably overlie the Mount Partridge Formation, and marked differences in strike between the two parts of Koolpin Formation near Coirwong Creek suggest that they may be separated by an unconformity. The difference in strike may be explained by northwest faulting. Drilling to investigate the relationship between the units is planned for 1977 or 1978.

DRILLING

Fourteen shallow stratigraphic holes were drilled in the Kapalga Sheet area to complete a drilling program commenced in 1975. The objectives of the program were to obtain fresh core samples for metamorphic-grade studies, and to compare the sequence either side of the ridge of Mount Partridge Formation at Kapalga Trig.

The sequence west of the ridge is feldspathic quartzite and quartzite (Mount Partridge Formation), overlain by mudstone, shale and siltstone, then by dolomite and interbedded schist, carbonaceous phyllite and phyllite, and finally phyllite with minor siltstone and quartzite bands (Fig. M5).

East of the ridge the sequence is feldspathic quartzite (Mount Partridge Formation) overlain by massive and banded dolomite, mica schist, mica-quartz schist, and minor quartzite and carbonaceous schist. The eastern sequence forms a downthrown block between Mount Partridge Formation and gneissic granite of the Nanambu Complex to the east (Fig. Mb). The presence of faulting is supported by major photo-lineaments, across which the thickness of Cainozoic cover changes sharply. Differences in the thickness of Cainozoic cover may also be accentuated by collapse of carbonate rocks.

The metamorphic grade of the Lower Proterozoic rocks increases from low greenschist facies at Kapalga Trig to amphibolite facies near the South Alligator River. The intensity of folding and cleavage also increases from west to east; dips in the less deformed strata range from 40^{o} to 70^{o}.

The western and eastern sequences probably both belong to the Koolpin Formation, rather than the Cahill Formation, which is characterized by a high proportion of coarser-grained terrigenous material.

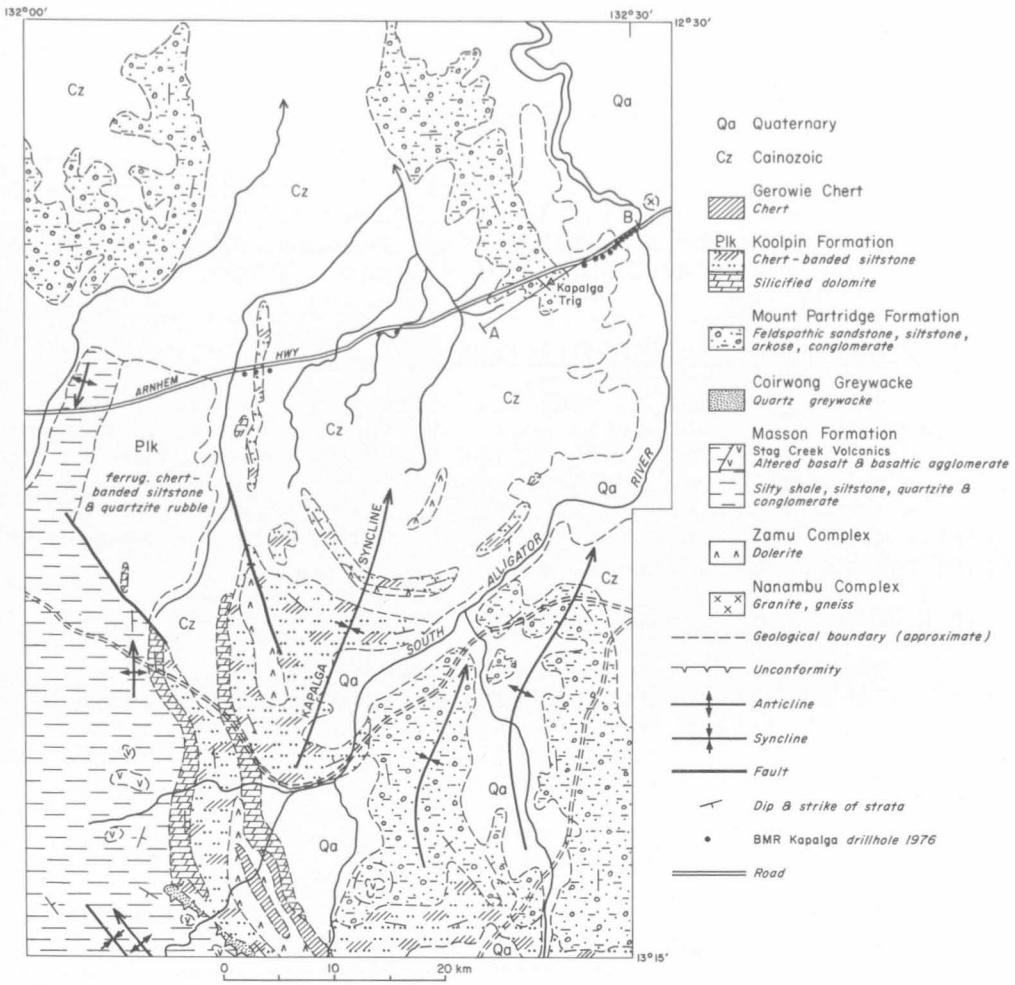


Fig. M5(a) Drill hole locations and surface geology, parts of Kapalga and Mundogie 1:100000 Sheet areas

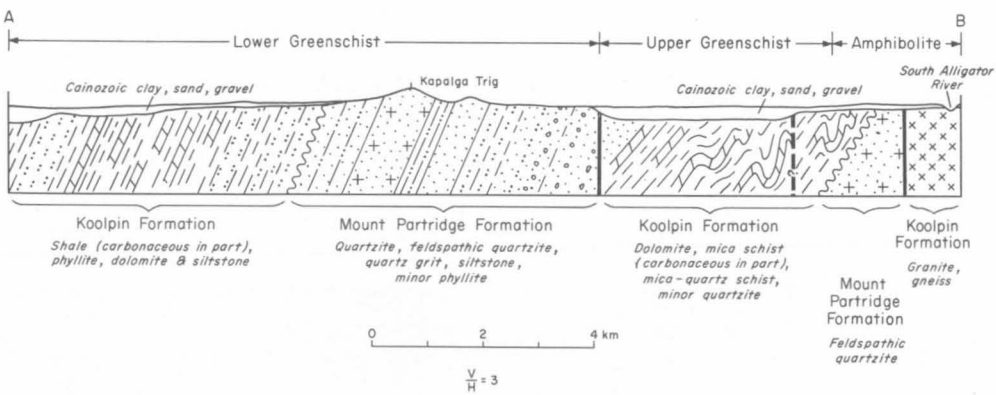


Fig. M5(b). Diagrammatic cross-section along drill traverse, Kapalga 1:100 000 Sheet area.

MISCELLANEOUS ACTIVITIES

Release of compilation sheets through AGPS

Compilation sheets at 1:50 000 scale covering most of the areas mapped are now available from the Australian Government Printing Service. Also available is a 1:250 000-scale clear-overlay map showing the distribution and regional structure of the Cahill and Koolpin Formations in the Alligator Rivers Uranium Field.

Diamond-drill hole into Cahill Formation

At the request of BMR, the Northern Territory Mines Branch drilled a diamond-drill hole into Cahill Formation exposed in a road cutting 11.6 km east of the South Alligator River bridge, along the Arnhem Highway. The hole penetrated 75 m of arkosic sandstone and conglomerate of unknown (?Cretaceous) age, overlying weathered schist to 132 m, where the hole was abandoned because of drilling difficulties.

Ranger Uranium Environmental Enquiry

Needham prepared a statement describing the regional geology of the Alligator Rivers Uranium Field and its uranium potential and presented it to the Enquiry, which he attended on 11-12 November 1975. A map showing areas of uranium potential in the same region was prepared at the request of the Enquiry during July 1976.

Fossil collection and description

A collection of Cretaceous fossils from the Junction Bay Sheet area, made during 1975, was described by S.K. Skwarko. The small molluscan fauna contained four bivalves, three of which are confined to the late Neocomian Unit 2, an indeterminate belemite, and a small gastropod. The collection was made in sandstone and siltstone of the Marligur Member, Bathurst Island Formation (formerly Mullaman Beds).

Quaternary arthropods, bivalves, gastropods, and wood fragments have been collected from South Alligator River floodplain sediments near the Kapalga landing, about 4-5 m below the surface of the floodplain. The arthropods are Thalassina squamifera de Man, and have been previously reported 7 km upstream from the mouth of the river, 50 km north of the Kapalga landing.

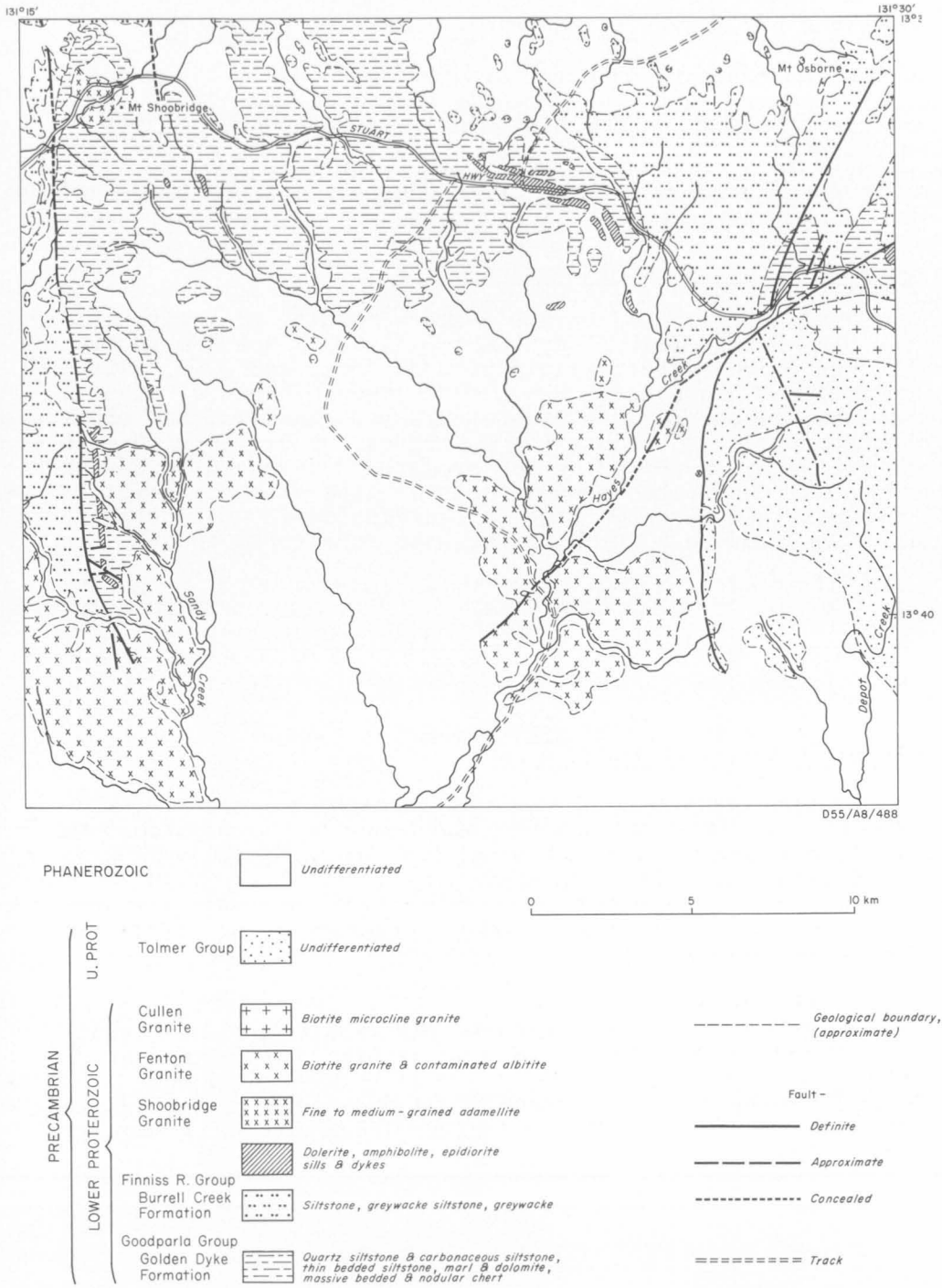


Fig. M6. Geological sketch map, northern half of the Tipperary 1:100 000 Sheet area, showing outcrops of Proterozoic rocks.

Deformation structures in Kombolgie Formation sandstone

Rectlinear and circular structures up to 250 m across are developed in sandstone directly underlying basalt in the Kombolgie Formation. Possible modes of formation have been researched in the literature, and a paper is being prepared describing these structures and postulating large-scale load casting between the sandstone and the basalt during, or soon after, basalt extrusion as an explanation of their development.

Pine Creek Geosyncline Discussion Group

A group formed by BMR workers holding an active interest in the Pine Creek Geosyncline was organized by Needham and Stuart-Smith, and convened fortnightly between April and July. The group included geologists, geochemists, geophysicists, mineral economists, geochronologists, supervisors, planners, and observers from other projects. Results and progress of projects in each of these fields was reported on and prompted much useful discussion. The group also provides a communication link with the joint BMR-CSIRO-mining company committee on the Pine Creek Geosyncline Uranium Study Group - (Dr John Ferguson represents the BMR on that committee).

WESTERN PINE CREEK GEOSYNCLINE

by

I.H. Crick

The objectives of this project are:

1. To gain a greater insight into the controls and distribution of ore deposits in the geosyncline.

2. To obtain more detailed information about the stratigraphy, structure and lithology of the Lower Proterozoic rocks of the Pine Creek Geosyncline.

3. To continue the semi-detailed mapping of the region between Rum Jungle and the Arnhem Land escarpment.

4. To revise the existing 1:250 000-scale geological maps of the region and to publish a new series of maps at 1:100 000 scale.

FIELDWORK

During 1976 work was concentrated on the re-mapping of the northern part of the Tipperary 1:100 000 Sheet area (see Fig. M6), which is occupied by Lower Proterozoic rocks; the southern part of the Sheet area is covered by Palaeozoic, Mesozoic and Cainozoic sediments. It is planned that the northern part of the Tipperary Sheet will be published with the Batchelor 1:100 000 Sheet. Fieldwork proved that the geological boundaries shown on the 1:250 000 Pine Creek Sheet and the 1 inch = 1 mile Tipperary Sheet needed little amendment.

Lower Proterozoic rocks in the northern part of the Tipperary 1:100 000 Sheet area comprise siltstone, schist, phyllite and calcareous and cherty rock of the Golden Dyke Formation, overlain by siltstone and greywacke of the Burrell Creek Formation. The Lower Proterozoic rocks are invaded by the 1760 m.y.-old Fenton Granite and by basic intrusives, which are tentatively assigned to the Lower Proterozoic. Near the western boundary of the Fenton Granite, outcrops of amphibolite are more extensive than previously mapped. The amphibolite is medium-grained, pale grey, and more or less concordant with the Golden Dyke Formation rocks which, at this locality, include ironstone, ferruginous and carbonaceous siltstone, locally containing chiastolite, grey hematitic quartzite, and quartzite-pebble conglomerate.

The Golden Dyke Formation is host rock to the uranium deposits in the Rum Jungle area and its correlatives, the Koolpin Formation and the Cahill Formation, contain the uranium deposits of the South Alligator River area and the huge Alligator River uranium field respectively. Within the Tipperary 1:100 000 Sheet area no concentrations of uranium are known, but gold and copper deposits have been mined and small concentrations of lead ore are abundant in the unit. Tin occurs in pegmatites, mostly concentrated along the Mount Shoobridge fault system.

RUM JUNGLE DISTRICT 1:100 000 SPECIAL SHEET
by R.G. Dodson

Drafting of the Rum Jungle District 1:100 000 special sheet is about 54 percent complete. A preliminary Record to accompany the map is in draft manuscript.

THE GRANITES-TANAMI PROJECT

by

D.H. Blake

The reconnaissance geological mapping of The Granites-Tanami region, an area of mainly Precambrian rocks, largely covered by sand, and situated between the Alice Springs region of central Australia and the Kimberley region of northwest Australia, was begun in 1971 and fieldwork was completed in 1973. The aims of the project were to prepare eight 1:250 000 scale maps accompanied by Explanatory Notes of the previously little known region, to prepare Records of each season's work, and to publish a Bulletin and 1:500 000 scale map synthesising the geology of the region. The 1:250 000 maps and Explanatory Notes have been completed and are either published or in press; a Report (no. 174) on the Birrindudu and Tanami 1:250 000 Sheet areas has been published, and four Records have been issued: three describing the geology of the other six 1:250 000 Sheet areas (1973/171, 1974/53, and 1974/102) and one on the results of stratigraphic drilling (1974/104). The text and figures for the Bulletin and the 1:500 000 scale map were completed in March 1976 by D.H. Blake.

ANTRIM PLATEAU VOLCANICS PROJECT

by

R.J. Bultitude

Little time was devoted to this project during the year. The draft manuscript of the report was reviewed and returned to the author for corrections. The regional map to accompany the text is awaiting final amendments by the author.

VICTORIA RIVER BASIN PROJECT

by

I.P. Sweet

All work on this regional mapping project was completed early in 1975. Nine 1:250 000 geological maps and Explanatory Notes and three reports have been published. A Bulletin summarizing the Precambrian geology of the region is in press; it should be printed early in 1977. The accompanying geological map at 1:500 000 scale is with the printer, and advance copies were received in August.

TENNANT CREEK

by

R.G. Dodson

The Record on the geology of the Tennant Creek area was completed and is in being edited. The Explanatory Notes and 1:250 000 First Edition map are with the map editing section.

McARTHUR BASIN

by

K.A. Plumb

Work is continuing within BMR and other organizations on aspects of the palaeontology and the newly-discovered evaporite deposits of the basin; several papers are in various stages of writing.

L.P. Black is currently analysing a new collection of glauconites from Elcho Island to test the anomalous isotopic ages reported by Plumb, J.H. Shergold, and M.Z. Stefanski in the BMR Journal; early results are tending to confirm the anomaly.

Planning is well advanced on a new multi-disciplinary study of the geological evolution of the McArthur Basin, and the distribution and genesis of its base-metal deposits. Field work is programmed to commence in 1977 and then continue for many years, with specialists from many fields of earth science contributing.

KIMBERLEY REGION

by

K.A. Plumb

1:500 000-scale geological maps of the West Kimberley and the North Kimberley are with the printer and have reached dye-proof stage.

The main activity in the Kimberleys during 1976 was the running of Excursion 44C for the International Geological Congress, in conjunction with I. Gemuts (Anaconda (Australia Inc.) and R. Halligan (North Broken Hill Limited). The Precambrian

geology of the whole Kimberleys was comprehensively synthesized by Plumb and Gemuts for the excursion guidebook (published by the IGC), in which many regional concepts and interpretations were presented for the first time.

ANTARCTICA

STAFF: R.J. Tingey, R.N. England, L.A. Offe, P.E. Pieters, J.W. Sheraton, D. Wyborn, W.B. Dallwitz, D.J. Ellis (only Tingey full-time)

INTRODUCTION by R.J. Tingey

The present on-going program of 1:250 000-scale mapping of the areas of exposed rock in the Australian Antarctic Territory is consistent with several of BMR's primary functions, particularly the obtaining of basic information on and the reviewing of the mineral resources of Commonwealth Territories. BMR geological mapping in Australian Antarctic Territory is part of the wider scientific program of the Australian National Antarctic Research Expendition (ANARE), an activity regarded by the Department of Science as the most worthwhile form of an Australian presence in Antarctica.

Reconnaissance geological mapping of the Australian Antarctic Territory was largely completed by the mid-1960s and systematic 1:250 000-scale mapping of the more extensive areas of outcrop was started in the late 1960s. Between 1968 and 1974 the Prince Charles Mountains were mapped and in 1975 field activities were moved to Enderby Land. The 1975 season was, for reasons described in the 1975 annual summary, essentially a failure, and the whole program of aerial photography, surveying, glaciology, and geology was repeated during 1976. Operations were centred at a new base camp near Mount King, in central Enderby Land, and the program was highly successful. Two BMR geologists, Offe and Sheraton, accompanied ANARE survey parties, combining assistance to the surveyors with reconnaissance geological mapping around trigonometrical stations. Although their movements were largely governed by the requirements of the survey program, Offe and Sheraton were able to visit 33 separate localities and examine in some detail the sapphirine-quartz locality described by Dallwitz (1968). They also visited the Soviet Antarctic Expendition's Moodezhanya Base where they were warmly welcomed in the first such ANARE visit to a foreign Antarctic base in several years. The 1976 program was mainly a thorough preparation for a major geological effort in 1977, when geologists will go into the field with complete colour vertical photograph coverage of the area to be mapped and 1:250 000-scale ERTS-derived base maps for the plotting of field data.

In November 1975 Tingey was a member of the Advisory Committee on Antarctic Geoscience Programs, convened by the Geological Society of Australia to advise the Minister for Science on future Antarctic geoscience programs. Later in the year he provided information and advice to the Offshore and International Division of the Department of National Resources for use in the preparation of a brief for the Australian delegation to the Paris meeting of the Antarctic Treaty Nations. The meeting was held in June; the main objective was to consider, in preparation for the full Treaty meeting in 1977, the question of Antarctic mineral resources.

Tingey attended the 25th IGC in August 1976 and presented a paper to Section 1A on 'The Geology, Geochemistry and Geochronology of the Prince Charles Mountains, Antarctica', co-authored with Sheraton, England, and Dr P. Arriens (Antarctic Division, Department of Science, formerly with RSES, ANU). A small exhibit depicting BMR geological mapping in Antarctica was prepared for the BMR display at IGC.

PRINCE CHARLES MOUNTAINS by R.J. Tingey

The last preliminary edition 1:250 000 geological maps of the Prince Charles Mountains were published during the year and the final laboratory studies completed. Sheraton's geochemical studies are summarized separately; England described the metamorphic rocks of the Prince Charles Mountains before resigning from the BMR. England's contribution and Arriens' geochronological work have made new interpretation of the geology of the Prince Charles Mountains possible.

The Prince Charles Mountains comprise an Archaean craton - the first reported from Antarctica - in the southern part and, north of 72°S, a Late Proterozoic mobile belt which is now represented by high-grade metamorphic rocks. Granitic intrusions, especially in the southern Prince Charles Mountains, are the more obvious manifestations of a widespread Cambrian thermal event that re-set Rb-Sr isotope systems in older biotite crystals.

The Archaean craton consists of metamorphosed granitic rocks about 2800-2900 m.y. old, overlain by generally lower-grade metasediments characterized by prominent white fuchsite-bearing quartzites. The granitic rocks have generally low Sr^{87}/Sr^{86} initial ratios and are believed to have formed during an amphibolite facies metamorphism that probably involved widespread intrusive activity. The minimum age of the metasediments is determined by a cross-cutting 2580 m.y.-old muscovite pegmatite.

At most localities the metasediments have kyanite-staurolite grade assemblages that are believed to be retorgrade, and probably attributable to the Late Proterozoic metamorphism.

However, higher-grade assemblages are seen in the metasediments at a few places, and some retrograde rocks retain relics of the earlier higher-grade metamorphism. The metasediments were metamorphosed between 2580 m.y. B.P. and the Late Proterozoic, and the geochronological data suggests some poorly defined tectonic activity between 2000 and 1700 m.y.

Basic dykes, principally of tholeiitic composition, were intruded into the Archaean craton before the Late Proterozoic metamorphism, and their presence or absence can be used with discretion to distinguish between the older and younger Precambrian rocks of the southern Prince Charles Mountains.

The Late Proterozoic metamorphism, although high-grade in the Prince Charles Mountains, decreased in intensity southwards and was lower amphibolite or greenschist facies grade in the southern Prince Charles Mountains. On the edge of the high-grade areas Rb/Sr isotope systems in certain granitic rocks were reset, and isochron ages of 1042 and 1223 m.y. have initial Sr^{87}/Sr^{86} ratios 0.87 and 1.10 respectively.

The main effect of the Late Proterozoic metamorphism upon the Archaean craton was metamorphism of the basic dykes and the overprinting of retrograde Kyanite-staurolite assemblages upon earlier assemblages, accompanied by local minor cataclasis. Relics of earlier high-grade assemblages are retained particularly well in rocks of pelitic composition, and include long needle-like aggregates of staurolite replacing sillimanite, skeletal remnants of pre-existing large garnets, and disequilibrium polymetamorphic assemblages such as garnet + cordierite + kyanite + staurolite + biotite + chlorite + quartz. Evidence of retrogression in the quartzofeldspathic rocks is less clear, although ubiquitous dark green ferrohastingsite clinoamphibole is almost certainly secondary.

Clastic sediments deposited on the Archaean craton in the Late Proterozoic after the intrusion of the basic dykes exhibit biotite or chlorite grade prograde assemblages resulting from Late Proterozoic metamorphism. Similar assemblages are seen in sediments associated with banded iron formations at Mount Ruker, but these rocks are belived to be of Early Proterozoic age and are intersected by metamorphosed basic dykes.

In the northern Prince Charles Mountains the Late Proterozoic metamorphism was a high-grade granulite or upper amphibolite facies-grade event. Initial Sr^{87}/Sr^{86} ratios are variable, and show that the metamorphism involved both the reworking of older material with a lengthy crustal history and the accretion of much younger material, probably via a two-stage process, from the mantle. The high-grade Late Proterozoic metamorphism affected a zone at least 500 km wide, and quite possibly extending 3000 km east-west, in the Gondwanaland super continent.

The main effects of the Cambrian thermal event have already been summarized and the post-Cambrian basic intrusives were described in the 1975 summary. The various metamorphic episodes identified by Arriens' geochronological work in the Prince Charles Mountains compare closely to Precambrian orogenic episodes identified in Africa but do not relate well to available geochronological data from India, even though the east coast of India is commonly juxtaposed against the Mawson coast in Gondwanaland reconstructions. The 2900-2800 m.y. episode in the southern Prince Charles Mountains is matched by an un-named orogeny in southern Africa, the poorly defined 2000-1700 m.y. event is broadly equivalent to the Eburnian tectogenetic cycle (2000 $\pm$ 200 m.y.), the Late Proterozoic event from 1200-900 m.y. corresponds to the Kibaran Cycle (1100 $\pm$ 200 m.y.), and the Cambrian thermal metamorphism was probably part of the Gondwanaland-wide Pan African tectogenetic cycle (600 $\pm$ 200 m.y.).

ENDERBY LAND by R.J. Tingey

Pieters and Wyborn's Record describing their 1975 work is being edited.

Offe and Sheraton had a successful field season principally because the base camp for operation was moved to a more suitable location. The major objective was achieved, i.e. to obtain a preliminary look at a number of scattered localities throughout Enderby Land in preparation for a large geological mapping effort in the 1977 season.

An extensive collection of specimens was obtained from the sapphirine-quartz locality first visited in 1958 by McLeod (1959) and described by Dallwitz (1968). The specimens have been examined in detail by England (electron microprobe analysis), Dallwitz (petrography), Ellis (petrology) and Sheraton (geochemistry), and field evidence indicates that the high-temperature (up to 1100^{o}C) high-pressure metamorphism noted by Dallwitz (1968) prevailed over a wide area of central Enderby Land. Sapphirine was also noted in aluminous rocks some 13 km east of the original locality and at Latham Peak, 60 km to the north. Soviet geologists report high-grade metamorphic rocks from all parts of Enderby Land, and therefore stratigraphic relationships such as are displayed in the southern Prince Charles Mountains are not expected to be apparent in Enderby Land. The main geological problems in Enderby Land are likely to be the metamorphic history and geochronology.

At the sapphirine-quartz locality the most common assemblage is: sapphirine + quartz + sillimanite + orthopyroxene + garnet + spinel, plus symplectites of cordierite, quartz, hypersthene and/or potash feldspar produced by the breakdown of pre-existing phases. Much of the sapphirine has broken down to

sillimanite, garnet and cordierite. Relict osumilite, a complex K-Fe-Mg aluminosilicate that is almost indistinguishable from quartz in thin section, has also been found. Most has apparently broken down to cordierite, orthopyroxene, orthoclase, and quartz. Osumilite has been recently reported in high-temperature moderate-pressure rocks in Labrador, Canada, but the Enderby Land occurrence is the only occurrence known in high-temperature high-pressure rocks. The sapphirine-quartz rocks also contain a relict phase that has been tentatively identified as a magnesian analogue of orthoclase, with apparently up to 30 percent substitution of Mg for K and compensating Al substitution for Si. The composition thus lies between the end-members $MgAl_2Si_2O_8$ and $KAlSi_3O_8$ (orthoclase).

These very preliminary results illustrate the type of problems likely to be encountered in Enderby Land. The very high-grade metamorphism does not augur well for the occurrence of economic mineral deposits, although such deposits may be present in post-metamorphic rocks. Although Soviet data indicate ages of up to 4000 m.y. for rocks from Enderby Land it is thought, by analogy with the Mawson Coast, that the main high-grade metamorphism possibly occurred about 1000 m.y. B.P., although the highest-grade event may be older.

Reference

DALLWITZ, W.B., 1968 - Co-existing Sapphirine and quartz in Granulite from Enderby Land, Antarctica. Nature, Vol. 219, No. 5153, pp. 476-477.

GONDWANALAND RIFTING, by R.J. Tingey

During the year apatite-bearing specimens from the Mawson Coast - Amery Ice Shelf - Prince Charles Mountains area were sent to Dr Gleadow at the Geology Department, School of Earth Sciences, Melbourne University for fission track age determination on annealed fractures in apatite crystals. Such fractures may be related to uplift that occurred at present-day continental margins during separation of the various fragments of Gondwanaland; fission track dating has been successfully used to date rifting and uplift in other parts of the world and this project if successful would allow accurate dating of the separation of the Gondwanaland fragments. Further collecting for this work will be done in the 1977 season and laboratory studies will continue through the rest of 1977.

GEOLOGICAL INVESTIGATIONS IN QUEENSLAND AND PAPUA NEW GUINEA

Supervising Geologist: D.H. Blake (until March)
K.R. Walker (after March)

MOUNT ISA-CLONCURRY PROJECT

by

G.M. Derrick

STAFF: BMR: G.M. Derrick, R.M. Hill
GSQ: I.H. Wilson

AIMS: The aims of the project are to map the Precambrian rocks of the Cloncurry Complex at a scale of 1:100 000, in order to delineate areas potentially favourable for mineralization, to revise the stratigraphy and structure, and to reconstruct the sedimentary, igneous and metamorphic history of the region.

FIELD ACTIVITIES

International Geological Congress

Derrick, Wilson and Hill conducted Excursions 5A and 5C in the Mount Isa region during August, for 35 and 50 participants respectively. Aspects of the stratigraphy, structure and economic geology were examined, and inspections were made of the Mount Isa and Mary Kathleen mines. Mammoth and Hilton mines were inspected after completion of the Congress.

Mary Kathleen area

Previously unrecorded wollastonite and fluorite-bearing marbles were located 5 km south of Mary Kathleen open cut in the Mary Kathleen syncline, during the course of the IGC Excursions. Wollastonite occurs as white fibrous rosettes from 1 to 5 cm diameter in association with granoblastic calcite, euhedra of ?grossularite 1 to 5 mm diameter, and thin veinlets of purple fluorite. Both wollastonite and fluorite occur preferentially in impure siliceous marble bands rather than in the more homogeneous marble or cherty quartzofeldspathic layers, and can be traced northwards into a skarn zone containing calcite-pyroxene-garnet assemblages. The transition is rapid, and involves a compositional change of ?grossularite to more iron-rich garnet (Fe^{3+} addition), possibly ?andradite; pale-coloured diopside becomes intensely green and more iron-rich (Fe^{2+} addition), the calcite content decreases, and wollastonite and fluorite disappear.

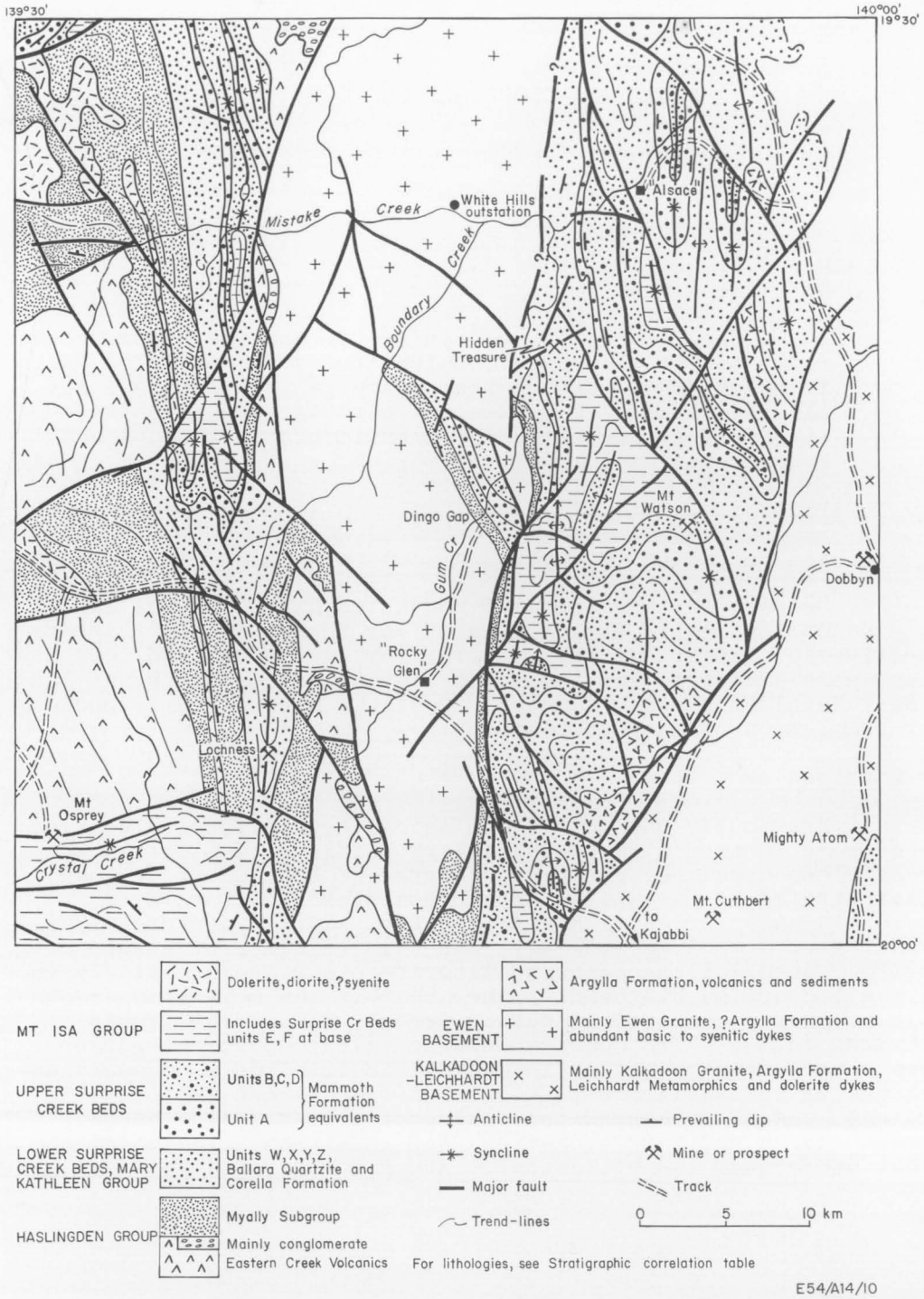


Fig. M7. General geology, Alsace 1:100 000 Sheet area.

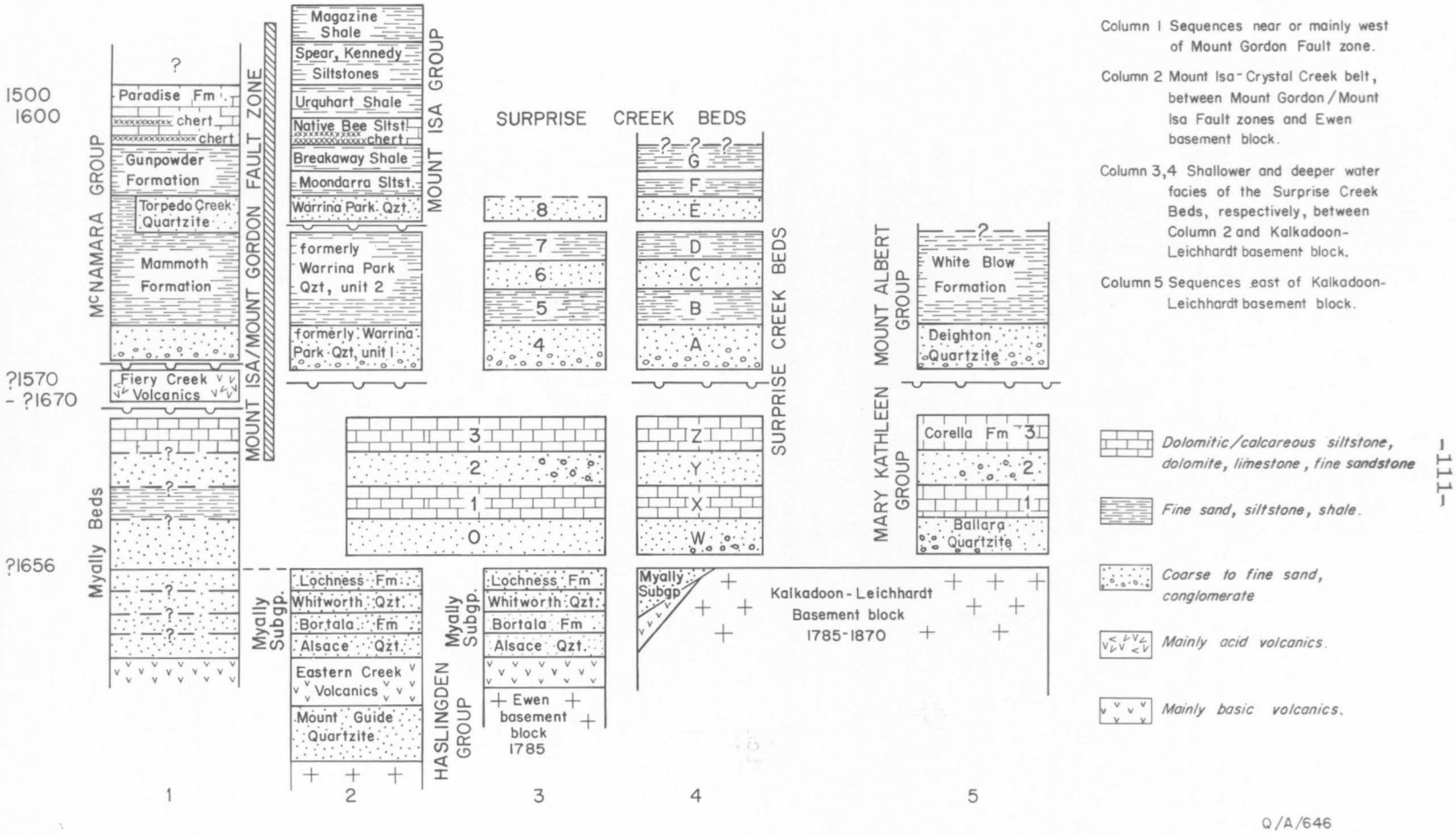


Fig. M8. Detailed stratigraphy and correlations north and northeast of Mount Isa.

Altered dolerite cuts the marble, and local contact metamorphism has caused recrystallization of iron sulphides to blebs 2-4 mm diameter, and fibrous wollastonite to aggregates up to 10 cm long. Thin leucocratic dykes contain abundant ?fluorite, and may be alkalic in type. A small deposit of scapolite-feldspar-calcite-apatite-magnetite pegmatoid near vesuvianite-bearing marble in the syncline may have resulted solely from metamorphic and metasomatic activity, but could also be a result of alkali igneous processes.

The stratabound fluorite appears to be of mineralogical interest only, but analyses of the fluorite-bearing strata are planned. Derrick and Hill sampled the marble, skarn and rhyolite dykes in the area, for uranium analysis and geochemical investigation by the BMR laboratory.

Alsace reconnaissance

Geological reconnaissance of the Alsace 1:100 000 Sheet area was undertaken during September, following photointerpretation of parts of the Sheet area. Fig. M7 is a geological sketch map of the area, and Fig. M8 summarizes the stratigraphy of the region.

Geology of the Alsace Sheet area is dominated by a central north-trending belt 10-15 km wide of basement granite and acid volcanics, the Ewen block, which is flanked to the east and west by parallel belts 10-20 km wide of younger sedimentary and basaltic rocks of the western succession. A wedge of the Kalkadoon Leichhardt basement block occupies the southeastern quarter of the Sheet, and some sediments of the eastern succession are exposed in the far southeast corner. The most significant results of the reconnaissance are as follows:

Eastern Creek Volcanics

A minimum thickness of about 5000 m of basalt is present north of Mount Osprey prospect; the volcanics thin rapidly for 12 km eastwards, and only about 900 m are preserved along the western edge of the Ewen block. This thickness reduction is accompanied, however, by an increasing thickness of coarse cobble and boulder conglomerate, apparently derived from the Ewen Block. No volcanics are preserved at Dingo Gap, and a hinge line marking the eastern limit of deposition of the Eastern Creek Volcanics may extend north and south from near Rocky Glen homestead.

Myally Subgroup

The four formations which comprise the Subgroup (Fig. M8) are traceable northwards from the Prospector Sheet area along the western or Bull Creek belt of the Alsace Sheet area. A sill of dolerite or diorite intrudes the Subgroup throughout the belt;

in the far northwest of the Sheet area it was previously mapped as Eastern Creek Volcanics, and has been described as syenite by companies working in the area.

The Myally Subgroup also appears to thin rapidly, from about 2000 m along Bull Creek to about 300 m at Dingo Gap to the east, although correlation of the basal units at Dingo Gap with Myally Subgroup remains to be demonstrated. At Dingo Gap the basal sequence of arkosic grit and conglomerate may represent the basin margin facies of Myally Subgroup deposition. If this is so, the actual eastern limit of Myally deposition may approximate a north-south line drawn between Alsace homestead and White Hills outstation.

Surprise Creek Beds

The Surprise Creek Beds are exposed in both the Bull Creek and Alsace belts; in the latter, sequences formerly mapped as Myally Beds are now mapped as Surprise Creek Beds. Sequences of shale at Crystal Creek, and near Mount Watson formerly mapped as Surprise Creek Beds, are now mapped as Mount Isa Group. A regional unconformity is present within the Surprise Creek Beds, and during this time break the Fiery Creek Volcanics were extruded west of the Alsace Sheet area. Despite close examination of critical localities, the Fiery Creek Volcanics have not been recognized in the Alsace Sheet area.

The lower Surprise Creek Beds consist of the informal units W, X, Y and Z which have been mapped previously in the Prospector Sheet area to the south. These units are equivalent to units 0, 1, 2, and 3, also in Prospector, but the numerical classification will now be discarded. Units W and Y are medium to coarse arenites, and X and Z finer-grained arenite, siltstone or dolomite. Along the edge of the Kalkadoon Leichhardt block basal arkose and conglomerate of unit W rest unconformably on Argylla Formation Volcanics. In the Bull Creek belt unit W rests conformably or disconformably on ferruginous sands of the Myally Subgroup. The contact, although apparently conformable, marks a significant change in sedimentation patterns, from chiefly coarse clastic sediments which thin eastwards (Myally Subgroup), to rapidly alternating quartzose clastics, siltstone and dolomite which appear to thicken northwards and eastwards.

Fig. M8 indicates that units W, X, Y and Z may be lithological correlatives of the Mary Kathleen Group east of the Kalkadoon-Leichhardt block. The Dingo Gap outlier has not yet been mapped, but it probably represents a transitional sequence between the Bull Creek and Alsace belts, and suggests that both the lower and upper Surprise Creek Beds were deposited across the Ewen block. Algal dolomite in unit X near the headwaters of Bull Creek suggest shallow shelf deposition in this region (cf. "shelf facies" in the Prospector Sheet area).

The upper Surprise Creek Beds contain units A, B, C and D. Unit A, a quartzite, is conglomeratic at the base, and overlaps unit Z, or more rarely, Y, of the lower Surprise Creek Beds. It also appears to thicken from west to east across the Sheet area; local thickness variations from 600 to 2500 m are present just south and southeast of Mount Watson, and are due mainly to a greater thickness of conglomerate. Units B and D are recessive sequences of fine sandstone and siltstone, separated in places by a thin brown to white quartzite, unit C. Fig. M8 shows that the upper Surprise Creek Beds may be equivalent to the Mammoth Formation west of the Sheet area, and to the Mount Albert Group east of the Kalkadoon-Leichhardt block.

Mount Isa Group

A distinctive white orthoquartzite, the Warrina Park Quartzite, marks the base of the Mount Isa Group throughout the Sheet area. It rests conformably on unit D, but elsewhere it may rest unconformably on older rocks. Unit E quartzite in the Alsace belt is now mapped as Warrina Park Quartzite also. The Moondarra Siltstone (formerly unit F of the Surprise Creek Beds) overlies the Quartzite in the Mount Watson area, and at Crystal Creek, south of Mistake Creek along Bull Creek, and in the far northwest of the Sheet area. A thick but probably incomplete sequence of Mount Isa Group is present at Crystal Creek, where the lower chert marker occurs at about the middle of the sequence, and is overlain by dolomites and shale with some intercalated potassic tuffs, equivalent to the Native Bee Siltstone.

Mineralization

Copper is present in basement volcanics and basic rocks in the Dobbyn-Mount Cuthbert belt, but mines in this area were not examined during 1976. Copper is widespread in units B, C and D on the Surprise Creek Beds, and in the overlying Warrina Park Quartzite. It appears to be broadly stratabound, and concentrations of mainly chalcocite in grey shale, siltstone and fine sandstone are present at Hidden Treasure and Mount Watson. The relation between these copper occurrences and facies distribution of units B, C and D will be further investigated. Some zinc and copper are reported in small amounts from the highly ferruginous Lochness prospect, in unit X of the lower Surprise Creek Beds. Copper is present at Mount Osprey, where basic volcanics, commonly with chalcopyrite in amygdales, are faulted against dolomitic siltstone of the lower Mount Isa Group. At Crystal Creek, companies have drilled the lower chert zone and gossanous zones within dolomites of the Native Bee Siltstone east and southeast of Crystal Creek, but results are not known to us.

Rationalization of nomenclature

With both company, BMR and GSQ geologists active in the region, care must be taken to avoid unnecessary proliferation of new stratigraphic names, and to ensure that existing names are used consistently. Some confusion currently exists over the term Myally Beds: these were redefined by us as the Myally Subgroup, a mainly clastic sequence (see Fig. M8). However, west of or near the Mount Gordon Fault Zone, the "Myally Beds" include units equivalent to W, X, Y and Z, the lower Surprise Creek Beds (Fig. M8), and the situation requires clarification. The unconformity within the Surprise Creek Beds will ultimately necessitate their redefinition. The upper division of units A, B, C and D appears broadly equivalent to the Mammoth Formation, a unit west of the Mount Gordon Fault, and could so be renamed in the future. The lower units W, X, Y and Z could be renamed as members of a Surprise Creek Formation, thus retaining a long-standing name, or be given a new name.

We also propose that units E, F and G of the Surprise Creek Beds be incorporated into the Mount Isa Group as the Warrina Park Quartzite, Moondarra Siltstone and Breakaway Shale, respectively. The numerical classification of the 'shelf facies' of the Surprise Creek Beds in the Prospector Sheet area (i.e. 0 to 8) may now be discarded, in favour of the letter classification as noted earlier.

Cloncurry area investigations

R. Hill examined areas of overhang Jaspelite and Soldiers Cap Group rocks east-northeast of Cloncurry, to determine facing in the sequence, but results are so far equivocal.

Visit to Broken Hill

Mount Isa and Arunta project geologists made a 3-day inspection in June of the regional and local geology in the Broken Hill district, under the guidance of geologists from the NSW Geological Survey and University of NSW. Broad lithological and radiometric age comparisons were made between the Broken Hill and Mount Isa regions south of Cloncurry, where Broken Hill-type zinc-copper mineralization was recently discovered.

OFFICE ACTIVITIES

Maps

First edition (colour) maps of the Mary Kathleen and Marraba Sheet areas were issued. Mount Isa is with the Map Editors for First Edition, and Prospector is being prepared by the authors for editing. Kennedy Gap Preliminary Edition was

issued, and Quamby was prepared for Preliminary Edition. Revision of the Cloncurry Sheet continued, and about two-thirds of Alsace Sheet was photo-interpreted.

Reports

A report on the geochemistry of black shale in Cloncurry DDH 5 by B. Duff was issued as a BMR Record. A Record describing the geology of the Prospector Sheet area has been delayed by other commitments, but is currently in progress. Reports on a 1973 drilling program and revisions to the Cloncurry Sheet are in progress, and contributions were written for a report on geophysical investigation near Cloncurry.

Publications

A BMR Bulletin describing the geology of Mary Kathleen Sheet area is with the printer. Stratigraphic nomenclature articles by Derrick, Wilson and Hill, parts I, II and III are issued, and IV, V and VI are with the Editors of the Queensland Government Mining Journal. Parts VII and VIII are with BMR editors.

The guide book by Wilson and Derrick to accompany IGC Excursion 5 in the Mount Isa region was published, and a paper by Glikson, Derrick, Wilson and Hill on tectonic evolution of part of the Mount Isa region appeared in the BMR Journal. Abstracts of papers given by Wilson and Derrick appeared in the IGC volumes of Abstracts.

Lectures

Derrick presented a lecture to the BMR symposium, entitled 'Some insights into old and new zinc mineration at Dugald River and Squirrel Hills, and uranium at Mary Kathleen', and a paper to the IGC entitled 'Origin and timing of uranium mineralization at Mary Kathleen, northwest Queensland'. Wilson's paper at IGC was entitled 'Possible Andean-type volcanics in the Proterozoic of northwestern Queensland'.

Geochronology, palaeomagnetism

U-Pb studies of zircons from various volcanic and plutonic units, by R. Page, are continuing. Rb/Sr ages of the older volcanics have been increased by about 100 m.y. in the light of the results by the U-Pb method. Detailed results are presented elsewhere.

The application of palaeomagnetism to the Mount Isa region was discussed; it may be of some use in magnetostratigraphy, to assist in intra and interbasinal correlations, the timing of mineralization in some deposits, and refinement of the Precambrian polar wander curve.

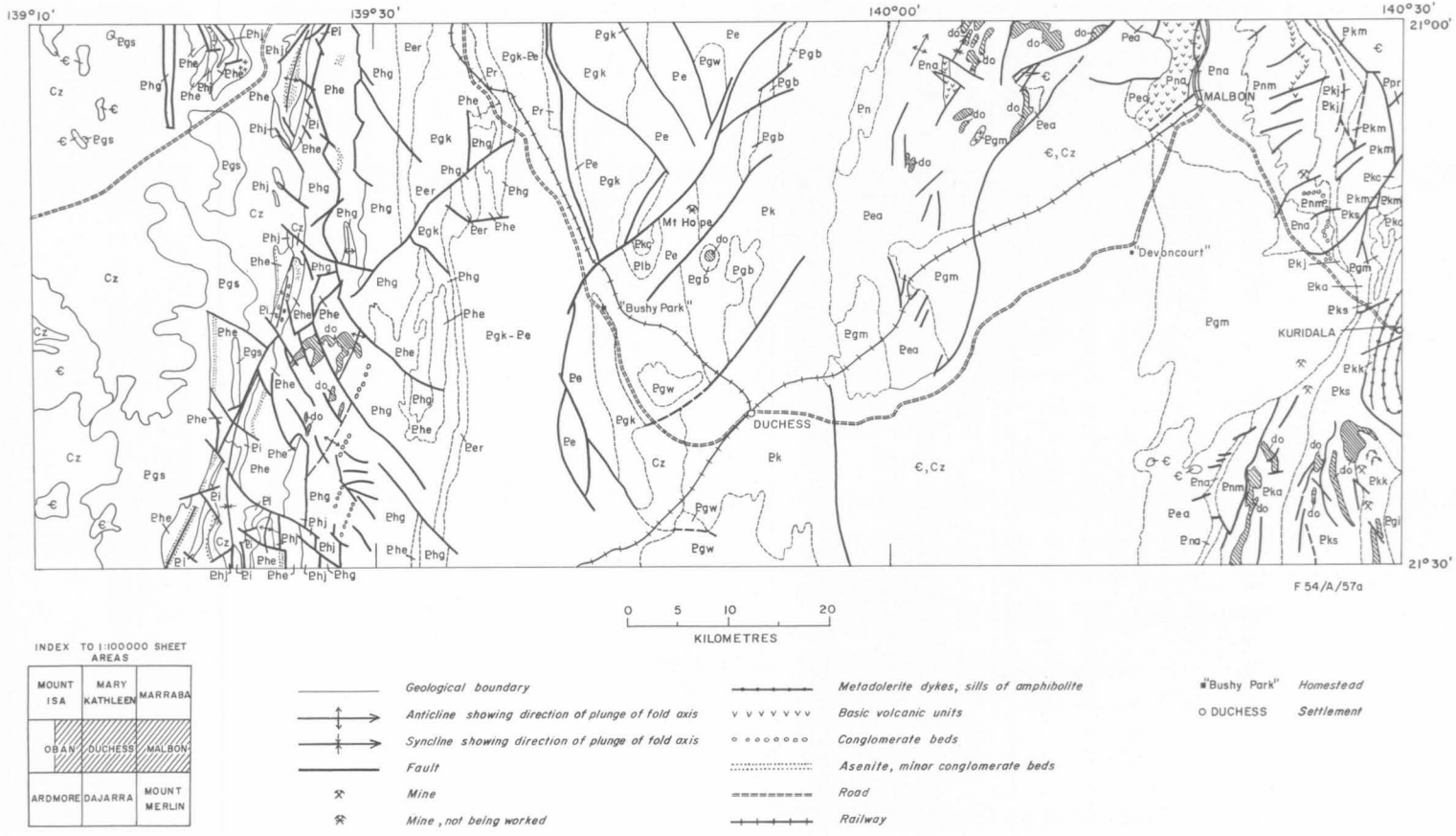


Fig. M9(a). Geological sketch map, Malbon, Duchess and Oban 1:100 000 Sheet areas.

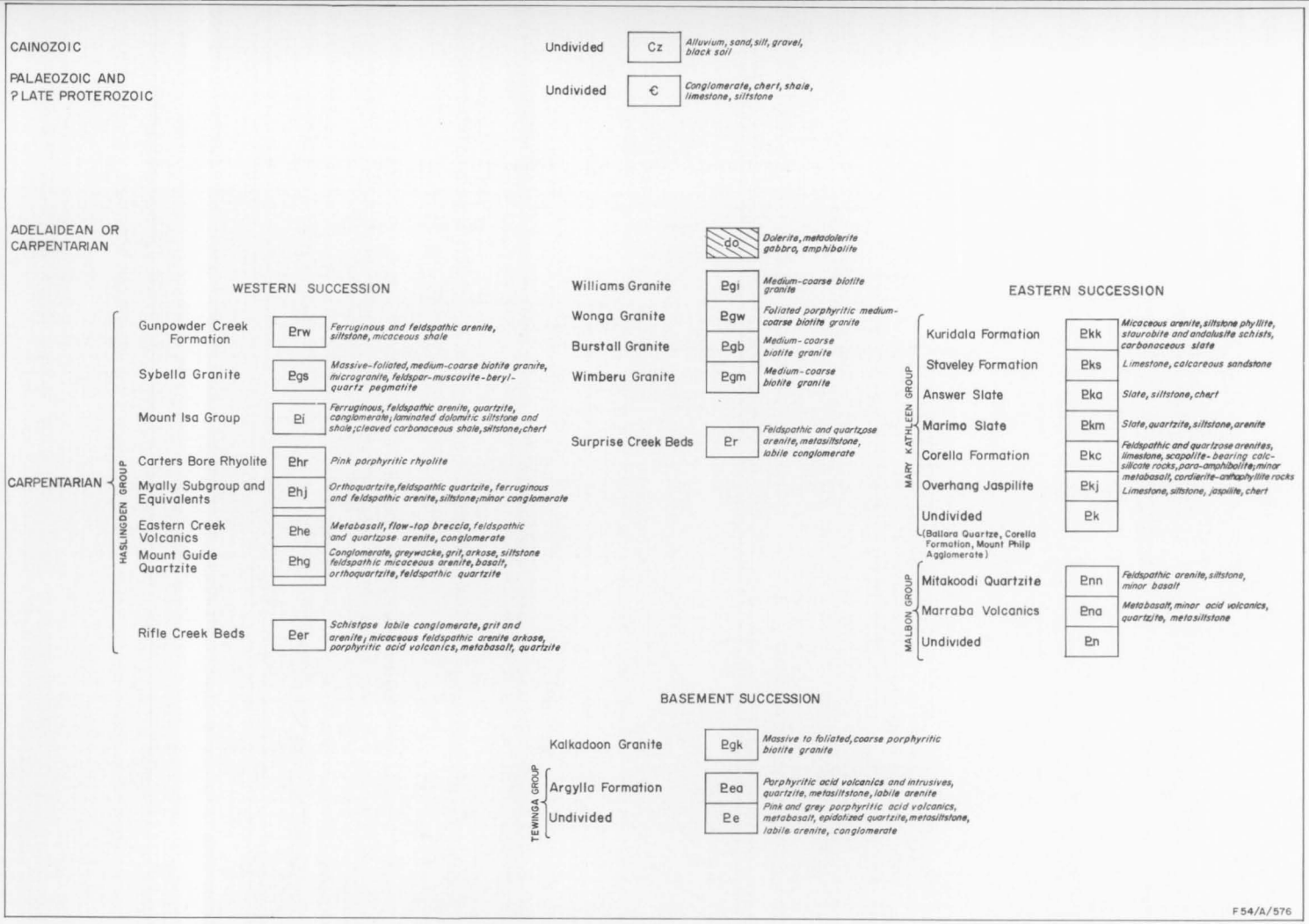


Fig. M9(b). Geological legend of the Malbon, Duchess and Oban 1:100 000 Sheet areas.

Other activities

R. Hill updated a bibliography of published work in the Mount Isa region, exclusive of company reports and Bulletin 51 listings.

An inaugural meeting of the Mount Isa Discussion Group was held in June, with a view to keep all interested parties informed of each other's program and progress, to provide a forum for brief presentation of important ideas and results, and to co-ordinate and forward ideas concerning future BMR programming.

DUCHESS PROJECT

by

R.J. Bultitude, C.M. Gardner, and T.A. Noon

STAFF: R.J. Bultitude, T.A. Noon (GSQ), C.M. Gardner, P. Blythe (draftsman).

The main aims of the project are: 1) to produce semi-detailed geological maps at 1:100 000 scale of the Precambrian rocks in the Duchess and Urandangi 1:250 000 Sheet areas; 2) to reassess the stratigraphy, mineral potential and geological history of the area; 3) to undertake detailed studies of specific aspects of the geology.

Introduction

The Precambrian rocks of the region form part of the Cloncurry Complex (Carter, Brooks and Walker, 1961) and have been divided into three main groups - an eastern succession and a western succession of predominantly stratified sequences separated by a north-south-trending acid plutonic and metavolcanic basement sequence (Fig. M9). The western succession crops out in the western and eastern parts of the Duchess and Oban Sheet areas respectively and is intruded by the Sybella Granite in the Oban Sheet area. The eastern succession is exposed in the eastern part of the Duchess Sheet area and the western and eastern parts of the adjacent Malbon Sheet area, and is extensively intruded by granitic rocks.

The eastern and western successions are separated by the Kalkadoon-Leichhardt Basement Block (Derrick et al., 1974) consisting mainly of acid plutonic and metavolcanic igneous rocks which form a basement to the eastern and western successions. A small inlier of basement rocks has also been mapped in the south-eastern part of the Malbon Sheet area. In sheet areas to the

north, the Kalkadoon-Leichhardt Basement Block is mapped as consisting of the Tewinga Group and Kalkadoon Granite (Carter, Brooks and Walker, 1961; Derrick, Wilson and Hill, 1976); these units continue south into the Duchess Sheet area. The Tewinga Group consists of (from the base) the Leichhardt Metamorphics, Magna Lynn Metabasalt and Argylla Formation. However, in the Duchess Sheet area, about 15 km west-northwest of Bushy Park, a major unconformity is exposed between rocks assigned to the Leichhardt Metamorphics and overlying units correlated with the Magna Lynn Metabasalt and Argylla Formation.

Geological mapping in the Duchess 1:100 000 Sheet area; by R.J. Bultitude

The oldest rocks exposed in the area occur as inclusions in, and larger masses closely associated with, contaminated, biotite-rich, coarse-grained, generally porphyritic granite in the western part of the Duchess Sheet area. These rocks are now schistose, gneissose or hornfelsic and their original lithology is commonly very difficult to determine. About 15 km west-northwest of Bushy Park they appear to be mainly metamorphosed, recrystallised acid and intermediate metavolcanics, with minor metabasalt. They are extensively intruded by cross-cutting and concordant veinlets; veins and small masses of pegmatite and leucocratic granite (of the Kalkadoon Granite) and it can be inferred that the country rocks have contributed to the contamination of the associated biotite-rich granitic rocks. Rocks similar to these have been mapped previously as Leichhardt Metamorphics (Carter, Brooks and Walker, 1961).

Leichhardt Metamorphics and associated biotite-rich granitic rocks west of Bushy Park are overlain by a thin sequence (ranging from less than 1 m to about 50 m thick) of metamorphosed, labile, schistose, micaceous arenite, arkosic sediments, grits and conglomerates containing angular clasts of vein quartz and pegmatite, rounded clasts of actinolite schist (metabasalt?) and large rounded granitic cobbles. The presence of these metasediments and the abrupt termination of granitic veins at the contact are interpreted as indicating the existence of a major time break between the Leichhardt Metamorphics - Kalkadoon Granite basement complex in this area and the overlying rocks.

The sequence overlying the basal conglomeratic unit consists of regionally metamorphosed basaltic lava flows and acid volcanics and associated thin quartzose and tuffaceous sediments, arkose and non-quartzose labile conglomerate. Together these make up a mappable unit, here informally termed the Rifle Creek beds. Metabasalts (actinolite schists) with amygdaloidal zones and numerous thin quartzite lenses recur at the base of the sequence and are probably correlatives of the Magna Lynn Metabasalt mapped to the north in the Mary Kathleen Sheet area. The overlying acid volcanics and interbedded metasediments, which are

correlated with the Argylla Formation, are overlain by a distinctive unit consisting mainly of quartz-poor labile conglomerate, arkose, metasiltstone and micaceous feldspathic arenite. This unit has been mapped as the basal part of the Mount Guide Quartzite in the Mary Kathleen Sheet area. Similar sediments are also present locally between layers of acid volcanics lower in the sequence. Locally, metamorphosed basaltic lava flows with interbedded thin quartzite lenses are exposed at the top of the acid volcanic pile and interfinger with the labile conglomerate sequence. The conglomerate contains subangular to well-rounded pebbles, cobbles and boulders of quartzite, acid and minor basic volcanic, and rare granite. It is generally schistose and many clasts are flattened and distorted. The matrix commonly forms more than 50 percent of the rock and probably has a high volcanic (tuffaceous?) content.

The Rifle Creek beds are overlain, apparently conformably, by ridge-forming sericitic feldspathic and quartzose arenites and quartzite, with minor pebbly beds, of the Mount Guide Quartzite. Bedding is commonly observed to be cut by a north-trending schistosity developed during regional metamorphism. The Mount Guide Quartzite is overlain, probably conformably, by the Eastern Creek Volcanics, a sequence of regionally metamorphosed basaltic lava flows, interlayered with locally thick lenses of quartzose and feldspathic arenite, and conglomerate. A conglomerate in the unit contains abundant subangular to rounded clasts of porphyritic acid volcanics.

East of Mount Hope, the basement rocks are overlain by the Bellara Quartzite - the basal formation in the eastern succession in that area - comprising thin lenses of fine to medium-grained quartz arenite, sericitic arenite and quartzite interbedded with calc-silicate rocks. The arenaceous sediments are typically very thin and in several places form only small lenses in a predominantly calc-silicate sequence.

Where mapped, the Corella Formation consists mainly of recrystallised limestones and calc-silicate rocks with minor quartzite, amygdaloidal and massive metabasalt, garnet-biotite schist, scapolite - biotite schist and rare cupriferous black shales and cordierite ± anthophyllite rocks. The formation has been extensively intruded by small masses of fine-coarse grained biotite, pegmatite, microgranite, and aplite, tentatively assigned to the Burstall Granite. The pegmatites and adjacent metasedimentary rocks commonly contain minor copper, and overly uranium mineralisation.

The granitic rocks of the basement succession, previously mapped as Kalkadoon Granite (Carter, Brooks and Walker, 1961) show a wide range in composition and texture. Northeast of Bushy Park the main type is a massive, coarse-grained biotite

granite with small pale green plagioclase grains and clots of biotite, and phenocrysts of white alkali feldspar. West of Bushy Park the granitic rocks are mainly coarse-grained, coarsely porphyritic biotite granites with large pale pink alkali feldspar phenocrysts and biotite-rich, porphyritic (in white, alkali feldspar phenocrysts) contaminated granites.

Geological mapping in the Malbon 1:100 000 Sheet area:
by T.A. Noon

There are two broad subdivisions within the Precambrian rocks of the Malbon Sheet area; (1) an inlier of metavolcanic basement rocks; and (2) younger metasedimentary rocks of the eastern succession. About one quarter of the Sheet area consists of Cambrian strata of the Burke River Outlier (de Keyser, 1968). Stratigraphic nomenclature in the Sheet area is based on that of Carter, Brooks and Walker (1961) together with revisions prepared by Derrick et al. (1971).

The oldest rocks in the Sheet area are acid metavolcanics, predominantly rhyodacites, and quartzites of the Argylla Formation. In the southeastern part of the Sheet area, inter-Volcanics have been assigned to the Argylla Formation. The Formation is extensively intruded by dolerite dykes.

The Marraba Volcanics overlie the Argylla Formation with apparent conformity. They consist of a predominantly basic volcanic lower member, and an upper member that is predominantly arenaceous and argillaceous. About 13 km southeast of Malbon the unit thins markedly and consists mainly of basalts and porphyritic andesite, with minor rhyolite.

The Mitakoodi Quartzite overlies the Marraba Volcanics conformably. A lower ridge forming quartzite unit is overlain by the Wakeful Basalt Member and recessive silty sandstone and sandstone. About 13 km southeast of Malbon the basalt appears to pass laterally into a conglomerate containing siltstone pebbles in a silty matrix.

Calcareous sandstone, pelite, jaspilite, chert and minor quartzite of the Overhang Jaspilite overlies the Mitakoodi Quartzite with apparent conformity. Although extensively faulted the Overhang Jaspilite can be traced almost to the southern boundary of the Sheet area.

The Marimo Slate and Answer Slate are broadly equivalent and consist of siltstone, sericitic siltstone, chert and black slate with minor quartzite. Where there is a complete sequence the Marimo Slate and Answer Slate both overlie the Overhang Jaspilite with apparent conformity.

Outcrops of Corella Formation about ten kilometres north of Kuridala are lithologically similar to, and extend laterally into, the upper part of the Staveley Formation. They are composed of sandstone, siltstone, calcareous sediments and breccia. The lower part of the Corella Formation is not exposed and the basal member of the Staveley Formation is a resistant sequence of siltstone, shale, slate and minor phyllite.

The Kuridala Formation is a sequence of staurolite-andalusite-garnet schists, arenaceous schists and siltstones, with an upper and a lower black slate member. Relationships between the Kuridala Formation and surrounding rocks are not clear. North of the Cloncurry River the contact with Staveley Formation is everywhere silicified and probably faulted. South of the Cloncurry River faulting is not evident and the formations appear to be conformable. Two possible correlations with the Kuridala Formation can be made. If the Kuridala and Staveley Formations are conformable, then the Kuridala Formation may correlate with the White Blow Formation mapped in the Mary Kathleen 1:100 000 Sheet area. However, parts of the Kuridala Formation in the Malbon Sheet area are lithologically similar to parts of the Soldiers Cap Group in the Cloncurry and Mount Angelay 1:100 000 Sheet areas and mining company geologists have suggested that parts of the two formations may be equivalent. It is anticipated that with further mapping in the Malbon Sheet area and sheet areas to the south, the relationship will be determined.

Copper mineralization is widespread throughout the Sheet area and is mainly associated with (1) basic bodies and shear zones in the Argylla Formations; (2) shear zones in the basic volcanic member of the Marraba Volcanics, and (3) the black shale members at the base and the top of the Kuridala Formation. The Silver Phantom mine near Kuridala is, at present, being redeveloped. It occurs in a sedimentary pendant, possibly Mitakoodi Quartzite, within the Wimberu Granite. The ore is mainly cerargyrite in a barite gangue.

Geological mapping in the Oban 1:100 000 Sheet area:
by C.M. Gardner.

Precambrian rocks are exposed in a north-northeast-trending belt along the eastern third of the Oban 1:100 000 Sheet area; the remainder of the area is covered by Cainozoic deposits.

The oldest rocks exposed in the Oban Sheet area are a sequence of immature pebbly to conglomeratic sandstones and greywackes formerly mapped as Eastern Creek Volcanics (Carter, Brooks & Walker, 1961). They are now correlated with the Lower Mount Guide Quartzite as mapped to the north in the Mount Isa 1:100 000 Sheet area (Hill et al., 1975) but may eventually be referred to a new unit, the Rifle Creek beds. In the Oban Sheet area, there is no evidence of an unconformity between these immature sediments and the overlying feldspathic quartzite and orthoquartzite of the upper Mount Guide Quartzite.

The upper Mount Guide Quartzite is overlain, along mostly faulted contacts by the Cromwell Metabasalt Member, the basal, and thickest, member of the Eastern Creek Volcanics. Sedimentary intercalations are rare in the lower part of the Eastern Creek Volcanics, but the Cromwell Metabasalt is overlain by a topographically prominent quartzite unit (50 - 150 m) thick which is overlain by the Pickwick Metabasalt Member - a sequence of thin or metabasalt flows, and interbedded lenses of limestone, quartzite and sandstone. Locally sedimentary rocks make up to half of the section.

In the northern and southern parts of the Sheet areas, the Eastern Creek Volcanics are overlain by up to 1000 m of distinctive generally schistose, vertically-dipping, quartzite and arenite. Outcrops in the southern part of the area were formerly mapped as Mount Guide Quartzite, or, where thin, were not distinguished from the unconformably overlying Mount Isa Group. The sequence is here correlated with part of the Myally Subgroup.

The Myally equivalents are overlain by the Mount Isa Group or, in one small highly deformed structural block in the northern part of the area, by its equivalents, the Carters Bore Rhyolite and Gunpowder Creek Formation. The base of the Mount Isa Groups is defined by a distinctive boulder conglomerate of variable thickness (generally less than 50 m); in places the conglomerate rests directly on the Eastern Creek Volcanics. The conglomerate and overlying friable ferruginous laminated sandstone and siltstone are referred to the Warrina Park Quartzite. The formation is exposed along the eastern and western margins of a broad synclinorium which extends from the Mount Isa Sheet area in the north into the Ardmore Sheet area to the south. The western margin of the synclinorium is fault-bounded by a possible extension of the Mount Isa Fault and is marked by abundant gossanous quartz veins. Other formations of the Mount Isa Group exposed in the synclinorium are the Moondarra Siltstone and Breakaway Shale, both apparently unmineralized.

The Eastern Creek Volcanics are intruded by the Sybella Granite. In most places contact effects are minimal but a narrow elongate lens of granite within Eastern Creek Volcanics in the central part of the Sheet area is surrounded by a wide aureole of mica schists, veined metabasalt (gneissic lit-par-lit rocks) cordierite schists and abundant pegmatite.

Structure of the Precambrian belt is dominated by north-northeast trends in faults, dykes and fold axes. Isoclinal folding of the Haslingden group has resulted in an apparent increase in the thickness of the Group in the southern part of the area.

LAWN HILL PROJECT

by

I.P. Sweet and A. Mond

STAFF: I.P. Sweet, A. Mond, J. Mifsud, L.J. Hutton (GSQ).

The primary objective of the Lawn Hill project is to document in detail the geology of the Carpentarian rocks in the area. This will allow correlations to be made with rocks in adjacent areas, particularly Westmoreland to the north, and ultimately should lead to a more accurate assessment of the mineral potential of the region.

A secondary aim is to remap the younger Precambrian rocks (the South Nicholson Group), and to describe their geology. The rocks contain substantial deposits of iron ore and were investigated by BMR and Broken Hill Pty Co. Ltd during the 1950s.

Parts of eight 1:100 000 Sheet areas will be studied during the project (Fig. M10), and maps at that scale will be issued. Mount Oxide Sheet area is not included in the Lawn Hill project, but it will probably be studied by geologists from both the Lawn Hill and Mount Isa parties, as it provides a critical link between Lawn Hill and areas farther south.

INTRODUCTION

Photointerpretation of Bowthorn and Lawn Hill Sheets was carried out early in 1976 by C. Maffi and C. Simpson of the BMR Photogeological Section, in collaboration with I. Sweet.

Fieldwork began in July 1976, and to date Bowthorn, Mount Oscar, Musselbrook, and about two-thirds of Lawn Hill have been mapped. It is hoped that most of the remainder of the area will be mapped during 1977, and that final checking, stratigraphic drilling and other follow-up work will be carried out in 1978. Preliminary maps at 1:100 000 scale will be issued when investigations in each Sheet area are completed.

FIELD ACTIVITIES

Carpentarian sequence

During the first systematic survey of the Lawn Hill area Carter & Opik (1961) subdivided the older Precambrian rocks (i.e. everything below the South Nicholson Group) into 4 units: the Myally Beds, Ploughed Mountain Beds, Weberra Granite and Lawn Hill Formation, in order of decreasing age.

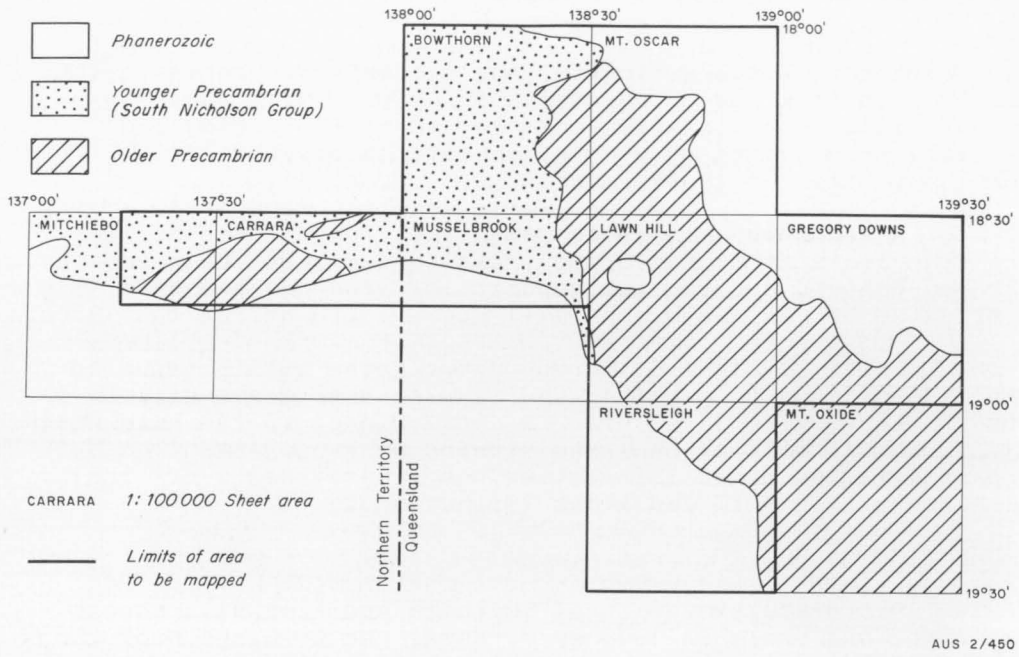


Fig. M10. Extent of Lawn Hill project area.

They considered that the Ploughed Mountain Beds were equivalent to units farther south, namely the Gunpowder Creek and Paradise Creek Formations, but considered the rocks in the Westmoreland region, to the north, to be younger. In the past few years several exploration companies have extended the boundaries of the southern units to the north, and refer to parts of the Ploughed Mountain Beds as "Gunpowder" and "Paradise Creek" equivalents. Cavaney (1975) erected an almost entirely new scheme of stratigraphic nomenclature. Until our mapping is further advanced, and stratigraphic sections in the southern area have been examined, the Ploughed Mountain Beds will be discussed only in terms of the 13 photogeological units established by Simpson.

The rocks mapped by Carter & Opik (1961) as Myally Beds consist, in part, of altered amygdaloidal basalts with thin quartzite and arkose interbeds (Pb in Fig. M11). These may be equivalent to the Eastern Creek Volcanics, or possibly to the Fiery Creek Volcanics, a unit described by Cavaney (1975) as mostly acid volcanics and clastics.

The Weberra Granite (Pg in Fig. M11) probably intrudes the basalts, but is overlain nonconformably by the Ploughed Mountain Beds, and does not intrude them as previously believed. The granite contains isolated blocks of schist up to several tens of metres long which are presumably remnants of a sequence older than the basalts.

The Ploughed Mountain Beds are separated from the basalts by an angular unconformity. The 13 photogeological units can be roughly grouped into about 150 m of basal clastics (Pm_{1-3}), 2000 m of carbonate (Pm_{4-6}), and 1800 m of upper clastics (Pm_{7-13}). The basal clastics include conglomerate and feldspathic sandstone (with copper staining) overlain by micaceous siltstone, shale and pyritic sandstone. The thickness of these basal clastics is variable, suggesting deposition on an uneven surface, but is up to about 150 m.

Included in the carbonate sequence is a basal zone of very weathered limonitic and cherty rocks; they include shale and sandstone, and may be dolomitic at depth. Although they are at present included in Pm_4, the remainder of which is laminated, intraclastic, and stromatolitic dolomite, the basal zone may prove to be a separate mappable unit. Pm_5 is a prominent photogeological unit which consists of stromatolitic, oolitic, and intraclastic dolomite, chert (presumably silicified dolomite), and sandstone. Pm_6, the upper part of the carbonate unit, is similar to Pm_4 and Pm_5. The position of its upper contact, with Pm_7, is somewhat arbitrary, as orthoquartzite and stromatolitic dolomite are interbedded. Ripple-marked and cross-bedded orthoquartzite characterise Pm_7, even though there is a substantial proportion of finer-grained clastics or carbonate rocks in most sections.

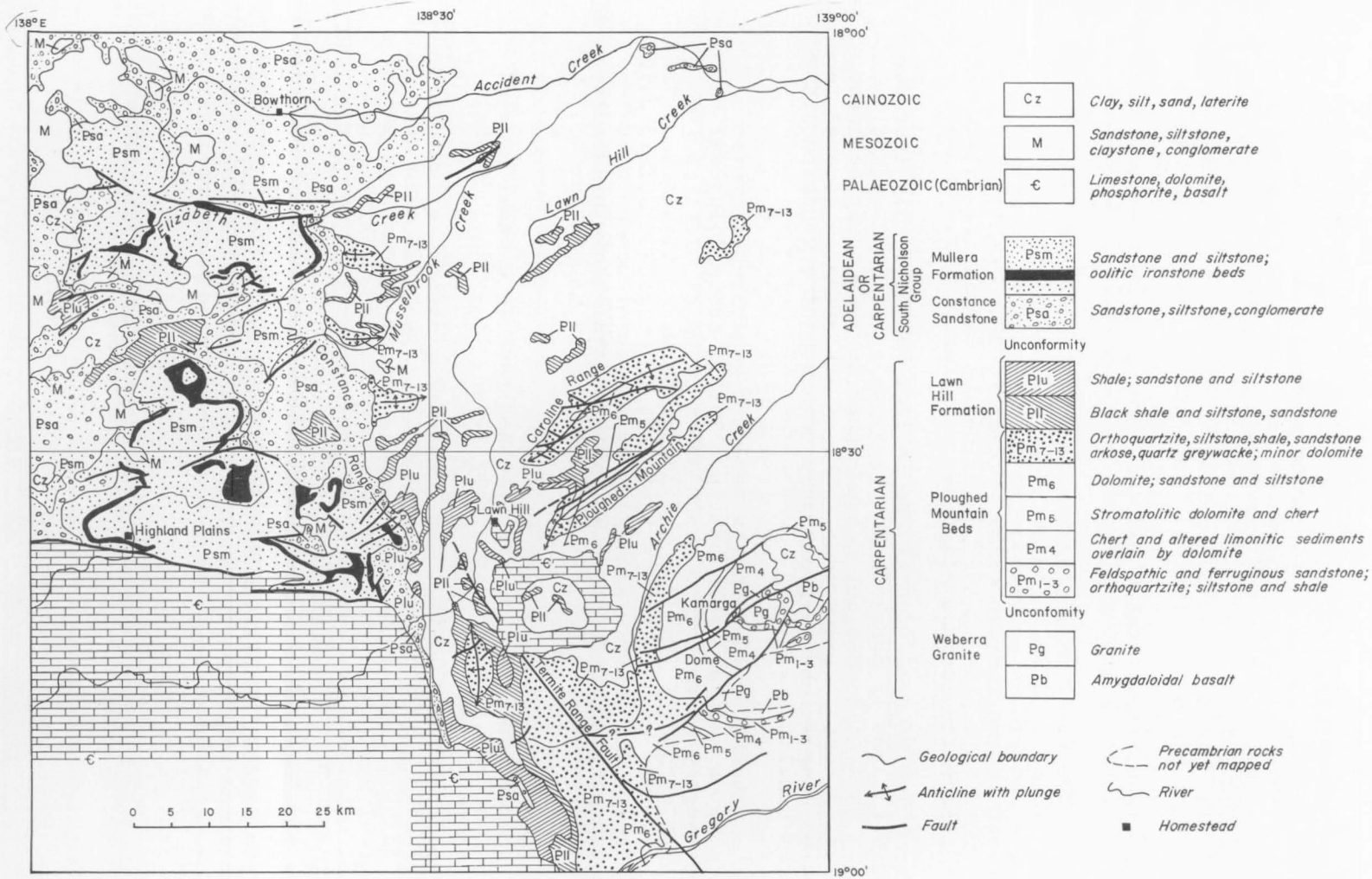


Fig. M11. Lawn Hill Project, 1976.

Units Pm_8 and Pm_{10} are predominantly siltstone, but include shale and sandstone beds of variable extent. The most prominent of these is Pm_9, which consists of a series of lenses of very coarse, clayey sandstone which lenses out in the Ploughed Mountain area.

Units Pm_1 and Pm_{13} are resistant units separated by a recessive unit of mainly siltstone (Pm_{12}). The sandstones forming the hard units are medium to coarse, moderately and poorly sorted feldspathic and clayey sandstone beds 1-3 m thick, separated by fine sandstone and siltstone beds of similar thickness. The resultant topographic effect is very striking. Pm_{11} grades northwards into a dark grey, silicified quartz greywacke in Ploughed Mountain and the Caroline Range.

The upper units of the Ploughed Mountain Beds have been recognized in three anticlines along the eastern margin of the Constance Range, where they were previously mapped as Lawn Hill Formation.

Conformably overlying the Ploughed Mountain Beds is the Lawn Hill Formation, a shale-siltstone sequence containing thin sandstone beds and minor volcanics. The shales are patchily exposed but the sandstone and siltstone (which is commonly silicified) form hogback ridges outlining the structure of the unit.

No unconformities have been observed within the Ploughed Mountain Beds and Lawn Hill Formation, but the South Nicholson Group overlies both with marked angular unconformity.

South Nicholson Group

A broadly folded sequence of Adelaidean or Carpentarian sediments up to about 3300 m thick (South Nicholson Group) covers most of the Bowthorn and the northern third of the Musselbrook 1:100 000 Sheet areas. The general geology of this area has been described by Carter & Zimmerman (1960), Carter et al. (1961), and exploration and drilling have been carried out by Broken Hill Pty Co. Ltd. (Harms, 1965).

The South Nicholson Group has been subdivided into two main units, the Constance Sandstone and the Mullera Formation, both consisting of several members. It is unconformably overlain by Middle Cambrian and probable Lower Cambrian volcanics, and Middle Cambrian limestones and dolomites.

The Constance Sandstone lies, disconformably and unconformably on the Lawn Hill Formation and Ploughed Mountain Beds. It is overlain conformably by the Mullera Formation. It is a dominantly arenaceous sequence ranging from coarse or very coarse poorly cemented and poorly bedded sandstones to medium or fine-grained, well bedded compact sandstones. Most of beds are medium-

grained, flaggy to massive, cross-bedded and ripple-marked. Conglomerate and pebble beds, often with angular fragments, occur extensively, particularly near the base of the sequence. They are not very thick, and in places contain boulders up to 40 cm in diameter. The sandstones are mostly poorly to moderately sorted and contain mica, clay and rare feldspar. Three siltstone members were recognized in the northern part of the Bowthorn Sheet area. They consist of micaceous siltstone and fine sandstone and help to subdivide the Constance Sandstone into 7 subunits: Unit Psa_1, Pandanus Siltstone Member, Unit Psa_2, Wallis Siltstone Member, Unit Psa_3, Bowthorn Siltstone Member, and Unit Psa_4. In places, where siltstone members are missing, it is rather difficult to recognize individual sandstone units and they were mapped as undivided Constance Sandstone.

The Mullera Formation crops out in the central part of the Bowthorn Sheet area, south of Accident Creek, and in the north of the Musselbrook Sheet area. It consists dominantly of thin-bedded, commonly micaceous siltstone, siliceous siltstone, shale and fine-grained sandstone.

The Mullera Formation includes three sandstone members 'Train Range Ironstone Formation', 'Middle Creek Sandstone', and 'Tidna Sandstone'. These consist of fine to medium-grained sandstones with little siltstone or shale. The lowest, the 'Train Range Ironstone Formation', contains a variable number of iron-bearing members, individually up to 21 m thick. Each ironstone-bearing member consists of iron-rich lenses of variable thickness interbedded with lenses of siltstone and sandstone. From one to four members are present in any one place and the number and grade of lenses within the member varies. The beds are unmetamorphosed. The stratigraphic nomenclature of the Mullera Formation will be revised when mapping is complete.

Distribution, lithology, and sedimentary structures of the Constance Sandstone and Mullera Formation indicate sedimentation occurred in a closed or nearly closed, shallow depositional basin with extensive marginal mud flats. The iron beds are oolitic hematite, siderite and chamosite beds of the Wabana (Newfoundland) type.

Correlations

Table 1 shows the most probable equivalents of the Lawn Hill sequence in the Westmoreland area. The sequences in both areas are broadly similar, consisting of volcanics overlain unconformably by a sandstone/carbonate/sandstone/shale sequence. In detail, it has not been possible to trace many units through both areas, but the Fish River Formation and the basal member of the Walford Dolomite are exceptions to this.

Structure

The Carpentarian rocks are moderately to tightly folded, and strongly faulted. The Termite Range Fault (a probable extension of the Carrier Shear south of the area mapped) divides the area into two structural domains. Dominant fold-axis trends range from northerly west of the fault, to easterly and northeasterly east of it. A prominent domal fold, the Kamarga Dome is present in the eastern Lawn Hill Sheet area. Dips are generally moderate (15°-45°), but in the anticlines which form Ploughed Mountain and the Caroline Range, Units Pm_{7-13} are steeply dipping (70°) to slightly overturned (85° to the northwest).

A system of northeast-trending faults with apparent right-lateral movement dominates the fault pattern of the area.

The South Nicholson Group is broadly folded. Folding is of the basin-and-dome type, with fold axes poorly defined but trending in general, east-west. The dips range from 0° to 30° except in the vicinity of faults where they are locally up to 90°. Faulting is especially prominent in areas of anticlinal uplift, and displacements of over 300 m are not unusual. Faults are commonly silicified. Jointing is common in the Constance Sandstone, and it is very pronounced in some of the coarser-grained and friable beds. In places, the joints have been etched out by weathering.

The iron formations crop out around the rims of the two major and several minor structural basins which are complicated by cross folding and faulting. The ironstone members are resistant to erosion and, therefore, tend to form hogback ridges, mesas, etc. Local relief is generally less than the 100 m in the vicinity of the ironstone ridges.

TABLE M1: Probable correlations between Westmoreland and Lawn Hill areas

Westmoreland	Lawn Hill
Doomadgee Formation	Lawn Hill Formation
Black Shale	
	Pm_{11} - Pm_{13}
Mount Les Siltstone	Pm_{8} - Pm_{10}
Walford Dolomite	Pm_{5} - Pm_{7}
	Pm_{4}
Basal Member	Pm_{4} (basal member)
Fish River Formation	Pm_{1} - Pm_{3}
Peters Creek Volcanics	Volcanics - Eastern Creek or Fiery Creek

WESTMORELAND PROJECT

by

I.P. Sweet

STAFF: I.P. Sweet, C.M. Gardner, J.E. Mitchell (all part-time)

The aim of the project, in common with others in the Mount Isa Province, was to elucidate the geological history of the area, assess its mineral potential, and publish reports and 1:100 000 scale maps detailing the results.

Fieldwork for the project was completed in 1974. A stream sediment geochemical survey undertaken in conjunction with the geological studies was completed in 1975, and is discussed elsewhere in this summary.

Preliminary editions of Hedleys Creek and Seigal 1:100 000 Sheets, and Westmoreland 1:250 000 Sheet (second edition) are now available, and three Records have been written: one by Gardner on basement granites is in the draft form, one by Mitchell (describing basement volcanics) is in press, the other by Sweet and Slater (describing the cover rocks) has been issued.

GEORGETOWN PROJECT

by

J.H.C. Bain, B.S. Oversby, & D.E. Mackenzie

STAFF: J.H.C. Bain[1], B.S. Oversby[1], D.E. Mackenzie[1], I.W. Withnall[1] (GSQ), E.M. Baker[1] (GSQ), A.G. Rossiter[2*], P.A. Scott[2*]. K.J. Armstrong[2*], D.R. Wilson[3*], J. Major[3*], P. Wilkes[3*], D. Robson[3*], L.P. Black[4*], P. Jorritsma[5*], P.L. Blythe[5*], J.T. Pollard[6*], N. Lodwick[7*], G. Brandon[7*].

[1]geology, [2]geochemistry, [3]geophysics, [4]geochronology, [5]drafting, [6]field assistant, [7]drilling, *part time.

The aims of the Georgetown Project, which started in 1972, are to revise and extend geological knowledge of the Georgetown Inlier, in particular to make more accurate and detailed geological maps; to investigate and determine regional geochemical and geophysical patterns, to determine the distribu-

tion, physical and chemical nature, source, and controls of the mineral deposits; to reassess the mineral resources and potential of the region; and to stimulate and assist mineral exploration there.

INTRODUCTION

In the first stage of the project investigations have been mostly confined to a north-south strip, 50 km x 150 km, in the central part of the Inlier (namely Georgetown, Forsayth, and Gilberton, and adjacent parts of Mount Surprise, Galloway, Forest Home, and North Head 1:100 000 Sheet areas). The field aspects of this first stage have now been completed with regional geochemical sampling of the Georgetown and Gilberton Sheet areas, ground checking of regional geophysical anomalies in the Forsayth and Georgetown Sheet areas, additional geological study of the Newcastle Range Volcanics, and semi-detailed geological, geochemical and geophysical investigation of the Mount Turner copper/molybdenum prospect discovered last year. Office activities in the form of laboratory studies, data processing and interpretation, report writing and map production, resulting from stage one field activities are continuing.

The second stage of the project - investigations into the Forest Home and North Head Sheet areas, and adjacent parts of the Esmeralda, Gilbert River, and Abingdon Downs Sheet areas, as far west as the eastern edge of the Croydon Volcanics, commenced with a geological reconnaissance, and some mapping in the north-east part of the Forest Home Sheet area.

FIELD ACTIVITIES

Newcastle Range

Study of the stratigraphy and structure of the Newcastle Range Volcanics in the southeastern part of the Galloway Sheet area has been completed, as well as some revision of the volcanic geology in the northern part of the Georgetown Sheet area. This work has increased our understanding of relationships among volcanic and associated rock units, and among various structural blocks in the Newcastle Range; it completes field investigation of the whole area of Newcastle Range Volcanics.

Rhyolitic agglomerates and ignimbrites dominate the northernmost part of the Newcastle Range Volcanics sequence. Agglomerates are thickest and coarsest in the extreme north; they decrease in relative importance southwards into the Georgetown Sheet area, although they are still common in unit Cn_{IV} (Refer Georgetown 1:100 000 Sheet Preliminary Edition Map). The northern area appears to be a structurally discrete, oval-shaped cauldron subsidence area of greater complexity than those to the east of

Forsayth and in the eastern Newcastle Range. The cauldron subsidence area is bounded by a complex of early high-angle faults and later, mainly shallow-dipping, rhyolite and microgranite dykes. It has been intruded by Elizabeth Creek Granite.

It is impossible to make detailed stratigraphic correlations between the northern cauldron subsidence area and the volcanic 'isthmus' of the main Newcastle Range in the Georgetown Sheet area, except in a few cases, because of facies changes and structural complexity. It appears however that rocks in the cauldron subsidence area are predominantly of the same age as those in units Cn_{IV} and Cn_{V} of the main range sequence.

Study of 74 rock specimens collected from the main Newcastle Range in the Georgetown Sheet area during the course of systematic geochemical sampling has helped to refine the definition of some volcanic rock units and the placement of some geological boundaries.

Ground checking in areas of aeromagnetic anomalies in the main Newcastle Range (Georgetown and Forsayth Sheet areas) found no correlation between magnetic highs and lows, and surface geology. An attempt was made to identify the source of a large positive anomaly in the upper Cattle Creek area by drilling, but because of drilling problems the hole was terminated at 33.45 m without having penetrated an obvious magnetic source.

Reconnaissance and regional investigation of the North Head and Forest Home 1:100 000 Sheet areas

A reconnaissance was made along most of the passable roads and tracks in all but the southernmost part of the area, in preparation for systematic geological investigations to be undertaken there next year.

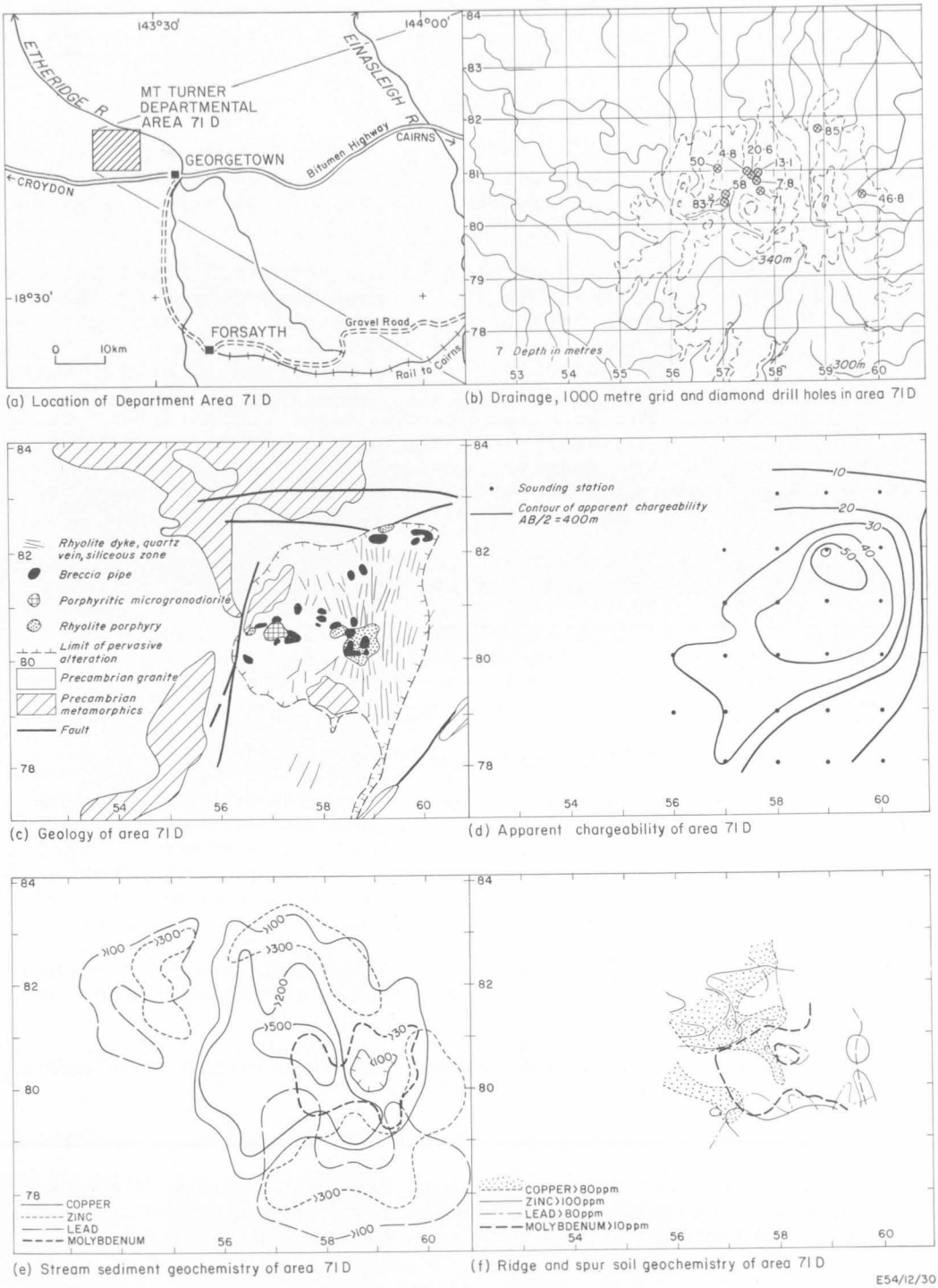
The Etheridge Formation, which grades eastward with both sedimentary and metamorphic facies changes into Robertson River Metamorphics, underlies most of this area. It can be divided into at least four units:

1. a phyllitic unit of essentially medium to dark grey phyllitic siltstone and mudstone;

2. a resistant unit of mostly dark grey siliceous siltstone and mudstone, and some chert;

3. a soft mudstone - siltstone unit locally carbonaceous and with characteristic dark bluish grey appearance in outcrop;

4. a highly carbonaceous, commonly pyritic, black siltstone unit (Stockyard Creek Siltstone Member) within unit 3.



(a) Location of Department Area 71 D

(b) Drainage, 1000 metre grid and diamond drill holes in area 71D

(c) Geology of area 71 D

(d) Apparent chargeability of area 71 D

(e) Stream sediment geochemistry of area 71D

(f) Ridge and spur soil geochemistry of area 71 D

Fig. M12. Mount Turner Copper-Molybdenum Prospect.

Unit 3 also contains a zone of mineralized silicified breccia that forms a series of elongate gossanous rubbly outcrops several kilometres long along the western side of the Forest Home/Candlow track in the Black Gin Creek area.

Several small elliptical plutons of medium-grained biotite granodiorite have intruded the Etheridge Formation in the Black Gin Creek area and produced narrow contact aureoles which contain either andalusite or sillimanite.

Examination and mapping of the Robertson River Metamorphics and Forsayth Granite in the northeastern corner of the Forest Home Sheet area were almost completed. The Robertson River Metamorphics there are mostly amphibolite facies schists (locally andalusite-bearing) and contain metadolerite/gabbro sills, some being well layered. They grade into migmatites in the Ironhurst-Lane Creek area. The granites cut the major folds (second phase of folding) in the metamorphics, and as they have a foliation that generally trends roughly parallel to the axial traces of third phase folds, they are believed to have been emplaced before or during the third phase of folding of the metamorphics.

Near Namul homestead, about 12 km west southwest of Georgetown, a line of breccia pipes crops out as small conical, bouldery hills 8 to 30 m across at the base. The breccias consist of angular fragments of altered granite and meta-sandstone with abundant crystalline cavity-filling quartz, and are similar to breccias in the Mount Turner area, 7 km to the north.

Mount Turner copper and molybdenum prospect

This mineralized, Palaeozoic hydrothermal alteration system 11 km west-northwest of Georgetown was discovered last year during a reconnaissance examination of the Forsayth Granite (1975 Annual Summary of Activities, p. 142). An area of about 70 km^2 (Fig. M12) enclosing the alteration zone was then gazetted a Departmental Area (Number 71D) by the Queensland Government, so that basic information could be obtained to aid the understanding of Palaeozoic metallogenic systems and the assessment of mineral resources. Mineral deposit studies are an important aspect of the project, and this type of deposit, in this area, has not previously been adequately studied or documented. It also presents an opportunity to test and improve regional geochemical and geophysical survey techniques.

Geology of the prospect. Detailed geological mapping by E.M. Baker, on enlarged aerial photographs at 1:10 000 scale, is essentially complete. The alteration system (Fig. M12) is within a small pluton of Proterozoic porphyritic muscovite-biotite granite (Forsayth Granite) containing minor muscovite

leucogranite/pegmatite (Digger Creek Granite?) and small enclaves of mica schist, quartzite, and amphibolite (Robertson River Metamorphics). It encloses several small bodies of porphyritic microgranodiorite, two small rhyolitic stocks and an associated dyke swarm, a rhyolitic ring dyke, and many younger pipeand dyke-like bodies of breccia, all probably of Late Palaeozoic age.

The alteration system is 3.5 to 5 km wide and comprises a large core of pervasive sericitic and minor potassic alteration (the latter near Mount Turner) an inner zone of dominantly fracture-controlled sericite-kaolinite alteration, and an outer zone of propylitic (essentially epidote-chlorite) alteration. Within these zones, and apparently controlling alteration to at least some degree, are numerous silicified, linear fracture zones and quartz veins. Silicified zones with marginal, mainly sericitic alteration, and commonly containing altered rhyolite, radiate beyond the main alteration zones and in numerous places contain galena, sphalerite and pyrite deposits, some of which were mined for their silver content. Mineralization in the inner alteration zones, as estimated from gossans, leached outcrops and drill core, consists of pyrite with or without chalcopyrite, and is concentrated in areas of most intense fracturing; it is stockwork fracture-controlled, and to a lesser degree disseminated. There is also some molybdenite scattered in silicified fractures and quartz veins.

The porphyritic microgranodiorite is similar to that at the disseminated copper/molybdenum prospect in the Mount Darcy area, 15 km to the west. It intrudes Forsayth Granite which is altered and cut by premicrogranodiorite silicified zones and quartz veins - some containing sulphides, and it contains minor amounts of disseminated pyrite and chalcopyrite. An adjacent shatter zone, formed by the emplacement of the stock, contains both disseminated and quartz-vein sulphides. A third episode of mineralization is represented by post-granodiorite quartz and quartz-sulphide veins.

The rhyolitic stocks and dykes also cut the early silicified zones and quartz veins, and are cut by late quartz and quartz-sulphide veins. They also locally contain some disseminated pyrite; fracture-controlled quartz-molybdenite mineralization is most extensive in their vicinity and may be related to their emplacement.

The microgranodiorite, rhyolite, and Proterozoic rocks are intruded by at least 27 pipe and dyke-like bodies of breccia. More than half of these breccia pipes are distributed in a 750 m x 4000 m zone trending northeast from near Mount Turner. These are polymictic breccias with dominantly angular granitic clasts in a milled granite matrix (milled microgranodiorite just north of Mount Turner). To the east, the remainder of the breccia pipes are within or adjacent to the rhyolitic stocks; they com-

prise angular rhyolite breccia with a rhyolitic matrix, angular rhyolite and microgranodiorite-rhyolite breccias with milled granite matrix, breccia with rounded clasts, and limonitic breccia. The latter is also present along some of the rhyolite dykes which are also commonly brecciated. Both rhyolitic and granitic breccias contain sparsely disseminated sulphides (pyrite ± chalcopyrite), and one pipe contains disseminated pyrite and molybdenite; coeval fracture-controlled pyrite-chalcopyrite, and pyrite-molybdenite are present in shatter zones and fractures formed during emplacement of the breccias. Late quartz and quartz-sulphide veins also cut the breccia pipes and related mineralization.

Geochemistry. About 160 stream sediment and soil samples (ratio 2:1) were collected from the 70 km^2 Departmental area to establish the presence or otherwise of anomalous levels of metals, and if present, to provide a guide to their distribution. The soil samples were collected from colluvium on the hillsides a short distance above selected stream sediment sites as a check, and to provide preliminary data for planning subsequent more detailed soil surveys. The minus 180 micron fractions of all samples were analysed for Cu, Pb, Zn, Ag, and Mo by atomic adsorption spectrophotometry and XRF in the BMR laboratory.

A stream sediment copper anomaly exceeding 10 km^2 in area (maximum value 958 ppm), and a molybdenum anomaly of 2 km^2 (maximum value 78 ppm), are flanked by peripheral lead and zinc anomalies. (Fig. M12).

More than 350 soil samples were collected at 100-m intervals along the tops of ridges and spurs within the area of the stream sediment copper anomaly, to better define the area of metallization. The less than 80-mesh fractions of the soil from immediately below the A horizon in the soil profile were analysed for Cu, Pb, Zn, and Mo. The results are shown in Figure M12, and indicate that for Mo there is close correspondence between soil and stream sediment anomalies but that for Cu there is poor correlation. Sampling was by D.J. Horton, J. Lam, and R. Adlard of the Geological Survey of Queensland; analyses by the Qld Government Chemical Laboratory.

Geophysics: Induced polarization (IP) depth soundings using Schlumberger arrays were made on a 1000-m grid to obtain a three-dimensional picture of the resistivity and chargeability of the altered rocks and their related mineralization, and adjacent unaltered wallrocks to help determine the subsurface distribution of sulphides and alteration zones, and to aid in the assessment of the size and nature of this copper/molybdenum prospect. Figure M12 shows the sounding sites and the chargeabilities measured with AB/2 = 400 m. Down-hole IP and resistivity logging confirmed the accuracy of the depth soundings. A distinct anom-

aly, roughly corresponding with an area containing greater than 1 percent sulphides as estimated from leached outcrops, is present within the alteration zone. Modelling and drill-hole information shows that essentially three, and locally four, layers are present in the geoelectric section and that they closely correspond with the soil/colluvium, weathered rock, and fresh rock layers in the geologic section. The chargeability and resistivity anomalies are coincident and present within the third (lowermost) layer. An anomalous fourth layer appears to underlie the anomalous part of the third layer at depths greater than 100 m.

Gamma-ray spectrometer and magnetic surveys were made to determine whether any patterns of potassium, uranium and thorium distribution, or any magnetic zones, are associated with the alteration zone. Results to date are inconclusive.

Drilling: Ten shallow scout holes (deepest 83 m) were drilled by a BMR Gemco rig to obtain fresh rock for petrographic and chemical studies, to obtain information in areas of no outcrop, and to provide control information for interpretation of the geophysical data. Consequently all holes were cored (total 400 m of BX, 3-cm diameter core) and geophysically logged.

Jubilee/Plunger geophysical study

Additional geophysical studies (I.P., magnetic, gravity, Turam, and TEM) were made in the Jubilee Plunger area to better define the lateral extent of the mineralized zone intersected by diamond drilling in 1975, and to check for other mineralized zones above and below it. This survey confirmed that the I.P. anomaly decreases in intensity away from the drill holes, thereby indicating that the mineralized zone may thin appreciably away from the hole, but also showed that there are other weaker anomalies to the east and west. This may indicate that the alteration zone containing the mineralization may be one of several parallel zones. No significant anomalies were obtained with the other geophysical methods.

Ground investigation of regional geophysical anomalies

Several aeromagnetic and radiometric anomalies located by the 1973 airborne survey (see below) were examined and one was drilled. No positive geological sources were identified. Investigations are continuing.

OFFICE ACTIVITIES

Petrographic and structural studies

Hundreds of specimens of the volcanic, granitic, and metamorphic formations of the Georgetown and Gilberton Sheet areas were examined petrographically to obtain more precise identification, description, and correlation of rock units. These

studies will be extended with chemical analyses of some specimens. Analysis by I.W. Withnall of structural data from the same area tends to confirm previous conclusions regarding the structural history and relations of the various metamorphics units.

Jubilee Plunger gold deposit study

Chemical, petrographic, and mineragraphic studies were made of the drill core acquired from holes drilled last year on geophysical/geochemical anomalies at the Jubilee Plunger reef and near the Big Reef mine. Results show that at Jubilee in the Late Palaeozoic? hot aqueous fluids containing S, CO_2, and base and precious metals penetrated along a fracture zone in the Robin Hood Granodiorite, mobilizing various elements (e.g. Si, Na & K) producing extensive wallrock alteration, quartz veining, and depositing metal sulphide concentrations. A deposit containing up to 10 000 tonnes per vertical metre of 'ore' assaying 7 g/tonne Au, 86 g/tonne Ag, 2.5% Zn, 1.1% Pb, and 0.35% Cu, or better is indicated.

The geophysical anomalies on the Big Reef line appear to have been due to graphite and minor pyrite.

Interpretation of regional geophysical data

Regional magnetic and radiometric data in the Forsayth Sheet area, gathered by the 1973 airborne survey, were examined and interpreted by D.R. Wilson: the magnetic data in terms of patterns, anomalies and possible sources; the radiometric data in terms of uranium, thorium, and potassium anomalies and their possible sources.

Magnetic data. The magnetic patterns, defined by particular levels of comparatively uniform magnetic induction, and by the trend, wavelength, and amplitude of minor variations in these levels, have superimposed on them magnetic features or anomalies, which in places distort the patterns and make them difficult to positively identify. In general, the main magnetic patterns correspond to the main geologic divisions, such as the Newcastle Range Volcanics, Forsayth Granite and Robertson River Metamorphics. However, the resolution does not match that of the geological control map; individual rock types in areas of complex geology cannot be distinguished, and thus, only the more extensive areas of these geological divisions are characterized by unique patterns. For example, the Forsayth Granite is characterized by the lowest magnetic induction in the Sheet area, - a smooth, flat pattern with minor induction variations of less than 50 nT; by contrast, the Newcastle Range Volcanics have slightly higher, more variable magnetic induction characterized by numerous close-spaced, low amplitude, short wavelength, short strike-length variations, and in places, clusters of high amplitude positive and negative anomalies.

Radiometric Data: There are no outstanding total count anomalies, and no significant uranium sources - U/Th chemical ratios are only about half those generally regarded as defining significant uranium sources, namely, 1.5. The Forsayth Granite is the most radioactive unit in the Forsayth Sheet area; a small area of porphyroblastic granite gneiss in the Einasleigh Metamorphics southeast of the Newcastle Range, also has high radioactivity. All other areas have much lower radioactivity.

Geochronology

Dating of granites, metamorphics, and acid volcanics by L.P. Black, of the Geochronology Group, continued throughout the year, as described elsewhere in this Summary. In addition, some dating by the Ar^{39}/Ar^{40} incremental heating method was carried out by D.C. Green of the University of Queensland under contract to the Geological Survey of Queensland.

Maps and reports

In addition to the published or issued maps, reports, and papers listed elsewhere in this Summary, the following are in various stages of preparation:

1. geological compilation sheets and observation point overlays at 1:25 000 scale for parts of Mount Surprise, Galloway, North Head, and Forest Home Sheet areas;

2. A geological data summary, Georgetown Sheet area;

3. a description of the mines, prospects and mineral deposits, Georgetown Sheet area;

4. a summary of exploration in the Georgetown Inlier since 1973;

5. an account of detailed geophysical investigations in the Georgetown area in 1975;

6. an interpretation of regional geophysical data in the Forsayth Sheet area.

NORTH SEPIK PROJECT, PNG

compiled by

D.E. Mackenzie

STAFF: D.S. Hutchison, M.S. Norvick (part-time)

The aim of the project was to investigate and document the geology and mineral resource potential of the region of Papua New Guinea north of latitude $4^{\circ}S$, comprising the Bewani, Torricelli, and Prince Alexander Mountains, and the adjacent parts of the coastal plains and the Sepik basin.

Field work for this project was completed in 1973, and during the past year, all maps and reports were essentially completed.

GEOLOGY

The North Sepik region consists of a Cretaceous- Lower Tertiary basement of igneous and metamorphic rocks overlain by a thick sequence of later Tertiary and Quaternary non-volcanic, mainly clastic sediments. Geological evolution of the region has largely been determined by a collision between the Indo-Australian (continental) plate and a Late Palaeozoic-Cainozoic island arc (the Bewani-Torricelli Arc) on the southwestern margin of the Pacific plate.

Volcanism began in the Bewani-Torricelli arc in the Late Cretaceous, and intensified in the Eocene when subduction developed beneath the arc following the Antarctic-Australian split. During the late Eocene and Oligocene, a great thickness of island-arc volcanics and derived sediments (the Bliri Volcanics) was deposited on oceanic crust, and, in the Prince Alexander Mountains area, on Lower Cretaceous metamorphic and plutonic rocks (Prince Alexander Complex) of uncertain origin. Also during this period the Bliri Volcanics were intruded by basic to acid plutons (Torricelli Intrusive Complex). Boulders of Permian plutonic rocks in the extreme southwest of the area are derived from a detached fragment or a northward-projecting tongue of Palaeozoic continental crust in Irian Jaya. Magmatism ceased in the early Miocene following the arc-continent collision.

South of the arc, Upper Cretaceous to Eocene sediments (now Ambunti Metamorphics) derived largely from the north were deposited in a deep trough, intruded by diorite (Amanab Metadiorite) in the Border Mountains region, and regionally metamorphosed during the collision process in the Oligocene. During the same period, and probably also as a result of the collison, ultramafic and basic rocks of probable Jurassic age (Mount Turu Complex) were upfaulted into the eastern Prince Alexander Mountains.

Collision was followed immediately by rapid uplift of the central basement axis and by the onset of sedimentation onto rapidly subsiding adjacent blocks, the Lumi, Aitape, and Wewak troughs. These sediments consist of thick sequences of poorly consolidated, mainly immature clastic material derived largely from local basement rocks. The unconformity at their base has been precisely dated in the N4 foraminiferal zone, younging to the east. The troughs were filled in three stages. A Miocene deepwater stage was characterized by early laterally discontinuous conglomerate and shallow-water carbonate adjacent to the basement, and by deeper-water fine-grained clastic, commonly turbidity current-deposited, sediments. Rapid filling of the troughs,

mainly from the west, during the Pliocene and Pleistocene resulted in shallow-water marine, marginal marine, and non-marine sedimentation becoming more prevalent. During the Quaternary, stream terrace gravels and alluvium were deposited inland, and reef carbonates were deposited along actively rising parts of the coastline.

The main structural feature of the area is a major easterly-trending system of strike-slip faults and thrust/strike-slip faults, with large vertical components, along the central basement axis. This system accommodated much of the crustal compression caused by the collision, and although lateral movements ceased at the end of the Pliocene, vertical movements still continue and the area remains seismically active. Folding of the cover sediments is intense near the basement axis, but lessens rapidly in severity away from it. Broad southeasterly-trending anticlines in the Lumi Trough probably formed over rising basement horsts.

ECONOMIC GEOLOGY

Exploration for hydrocarbons has been active in the area since about 1925, but although several oil and gas seeps are known, it has had no success. Marine source rocks are abundant, but may be too immature for oil to have formed. Some Miocene and lower Pliocene sandstones in the Lumi Trough have adequate reservoir characteristics. The flanks of large gentle anticlines in the Lumi Trough could contain stratigraphic traps, and the sequence in the Maimai Anticline appears to be much thicker than that in the Bongos Anticline, which was drilled unsuccessfully. Miocene and Pliocene reef carbonates in the western part of the Aitape Trough, and along the south side of the Serra Hills may be suitable reservoir rocks.

Alluvial gold, derived from cover conglomerates, is being worked by local villagers in the Prince Alexander Mountains, and traces of copper, nickel and platinum are associated with igneous basement rocks throughout the region.

MAPS AND REPORTS

Maps and Explanatory Notes covering the Aitape and Vanimo (combined), Wewak and Sepik 1:250 000 Sheet areas were completed. Compilation of Ambunti 1:250 000 Sheet area (adjoining Wewak to the south) and drafting of Explanatory Notes (in conjunction with Geological Survey of Papua New Guinea) were completed, and assistance was also given in the compilation of May River 1:250 000 Sheet, south of Aitape Sheet.

The manuscript of a Bulletin entitled 'Geology of the North Sepik Region, Papua New Guinea' is complete, and a report on the basement geology is in print. Twenty-two new names were approved by the Stratigraphic Nomenclature Committee.

NEW BRITAIN PROJECT, PNG

compiled by

D.E. Mackenzie

STAFF: R.J. Ryburn

Objectives of the New Britain project are to produce geological maps at 1:250 000 scale covering the island southwest of the Gazelle Peninsula (south of 5°S) and an integrated report on the geology of the whole island. Maps and Explanatory notes covering all five 1:250 000 Sheet areas - Pomio, Talasea-Gasmata (combined), and Cape Raoult-Arawe (combined) have been published. Preparation of a Bulletin entitled 'Geology of New Britain, Papua New Guinea' is in progress, and is expected to be completed during 1977.

MISCELLANEOUS PROJECTS, PAPUA NEW GUINEA

compiled by D.E. Mackenzie

STAFF: R.J. Ryburn, P.E. Pieters, G.P. Robinson

R.J. Ryburn continued work on the South Sepik blueschist project. He was mainly occupied with theoretical considerations of mineral equilibria under high pressure-low temperature metamorphic conditions, directed towards estimation of pressure, temperature and fluid phase composition during formation of mineral assemblages.

P.E. Pieters completed compilation of Kikori 1:250 000 Sheet area (Papua New Guinea), and completed Explanatory Notes on the area. He also compiled a tectonic map of Papua New Guinea and Irian Jaya for the 1:15 000 000 Tectonic Map of the World.

G.P. Robinson contributed to an article with A.L. Jaques (A.N.U.) on the tectonic evolution of northeastern mainland Papua New Guinea, to be submitted for external publication.

IRIAN JAYA PROJECT

Compiled by

D.E. Mackenzie

STAFF: D.S. Trail*, R.J. Ryburn, G.P. Robinson, P.E. Pieters, D.S. Hutchison; Staff of the Geological Survey of Indonesia.
*Department of National Resources, Offshore and International Division.

IRIAN JAYA PROJECT

by

D.S. Trail

STAFF: D.S. Trail (Aust. Develop. Assistance, Agency (ADAA)), R.J. Ryburn, G.P. Robinson, P.E. Pieters, D.S. Hutchinson, *H. Sumadirdja, *N. Ratman, *Kastowo, *M. Masria (*Geological Survey of Indonesia).

A combined party of BMR and Geological Survey of Indonesia personnel under the leadership of Trail (ADAA) worked in the Birds Head region of Irian Jaya between August and November. The party carried out a preparatory study, funded by ADAA and concerned with the feasibility of systematic geological mapping of the whole of Irian Jaya as an Australian aid project.

Ryburn, Robinson, Pieters and Hutchison were released on leave-without-pay by BMR to take up short-term positions as overseas experts with ADAA. The party worked in the field by arrangement with the Australian Defence Department, supported by units of the Royal Australian Survey Corps and the RAAF, which were currently engaged in a topographic survey of Irian Jaya.

Ryburn, Kastowo, Pieters and Masria initially carried out a geological reconnaissance in conjunction with Army survey parties in the western and southern parts of the Birds Head region. They later joined Trail, Sumadirdja, Robinson and Ratman in Manokwori from where the party mapped most of the Manokwori 1:250 000 Sheet area and undertook a reconnaissance of the northern and eastern parts of the Birds Head area.

Hutchison joined the party in mid-September and Ryburn left the field late in October to undertake an assessment of the facilities of the Geological Survey headquarters in Bandong. All BMR personnel returned to Australia early in November.

In the Manokwari area a monotonous unit of slate, phyllite, and quartzite is intruded by large masses of granitic rocks and is locally affected by high-grade thermal metamorphism. It is separated by a major fault from andesite and volcanogenic sediments of the Arfak block.

Farther west the geology is complex in the vicinity of the Sorong Fault. Andesitic and basic volcanics, ultrabasic rocks, and a large intrusive complex were briefly examined as well as Tertiary sediments and brecciated limestone.

Mesozoic and Tertiary sediments were also examined in the southern part of the Birds Head area and moderately high-grade metamorphics were noted in the east.

A detailed proposal is being prepared for ADAA on the possibilities of providing assistance to the Geological Survey of Indonesia with 1:250 000 scale geological mapping of Irian Jaya.

VOLCANOLOGY AND ORE GENESIS, PNG

by

R.W. Johnson, D.E. Mackenzie (part-time), and
I.H. Crick (part-time)

G.A.M. TAYLOR MEMORIAL VOLUME by R.W. Johnson

A volume entitled 'Volcanism in Australasia' was published by the Elsevier Scientific Publishing Company, in memory of the late G.A.M. Taylor, a former BMR officer. In addition to an account of Taylor's life, twenty-eight research papers on a wide range of volcanological topics are presented by authors from BMR, universities, geological surveys, and other organisations throughout Australia, New Zealand, Papua New Guinea, and the Solomon Islands.

Contributions by officers currently employed by BMR include the following topics, (all except the first dealing with volcanic areas in Papua New Guinea): the Cambrian flood basalts of northwestern Australia (R.J. Bultitude), volcanism and plate tectonics in the south Bismarck Sea (R.W. Johnson), eruptive history of Manam volcano (W.D. Palfreyman), geology of Long Island (R.W. Johnson), pyroclastic deposits of Witori volcano (D.H. Blake), thermal infrared survey of the Rabaul area (W.J. Perry and I.H. Crick), geology and petrology of the Highlands volcanoes (D.E. Mackenzie), geology of Madilogo volcano (D.H. Blake), crustal structure beneath Mount Lamington (D.M. Finlayson, B.J. Drummond, C.D.N. Collins, and J.B. Connelly), geology and petrology of islands off New Ireland (R.W. Johnson and D.J. Ellis), eruptive history of Bagana volcano (R.J. Bultitude),

CAINOZOIC VOLCANIC STUDIES

Highlands volcanoes by D.E. Mackenzie

Much of the work on the Papua New Guinea highlands volcanoes has now been published, or is in manuscript form to be submitted for publication. Two manuscripts written in conjunction with R.W. Johnson and I.E. Smith are summarized below. A third, published in the Taylor Memorial Volume is summarized here:

Nature and origin of Late Cainozoic volcanoes in western PNG:- Sixteen Late Cainozoic centres in western Papua New Guinea rest on 25-30 km thick Palaeozoic sialic crust and up to 10 km of post-Palaeozoic sedimentary and volcanic rocks. One rests on a 35 km-thick pile of eugeosynclinal sediments and volcanic rocks, fourteen of the centres are deeply eroded stratavolcanoes, and the last a ring-like cluster of lava domes. Basaltic rocks are dominant in eleven centres, and these range from high-K, over-saturated (shoshonitic) types, through lower-K saturated types to low-K types just saturated to slightly undersaturated in silica. Other rock types in these centres, and the dominant rock types in the other six centres, are low-Si andesite and andesite with high to moderate-K contents. The magmas originated in the upper mantle low-velocity layer following plate collison in the late Oligocene to early Miocene, and subsequent crustal warping and uplift continued into the Pliocene. Complex chemical variations were produced by mantle inhomogeneity, various types and amounts of partial melting in rising diapirs at various levels, and various rates of ascent and degrees and types of crystal fractionation at the base of and within a mechanically inhomogeneous crust.

Detailed aspects of the work not covered by these articles are to be compiled in a detailed and complete report, entitled 'Volcanoes of the Papua New Guinea Highlands: volcanism on a continental margin and its relationship to subduction', which is nearing completion. The most important of these aspects are:

1. The occurrence of island arc-type volcanic rocks of Cretaceous age in the Kubor Range-Jimi Valley-Schrader Range area.

2. The occurrence in many basaltic rocks of coarse-grained aggregates of early-formed (at depth) crystals, principally olivine and chromium-rich spinel. These are a direct clue to the evolution of the magmas, and also provide clear evidence of their ultimate origin in the mantle.

3. Rare earth element determinations by R.W. Johnson on several rocks from selected volcanoes point to a garnet-bearing source region, but not an amphibolitic or eclogitic (subducted basaltic crust) source.

4. High copper contents in the basaltic rocks, where Cu occurs as discrete sulphide grains in the groundmass as well as in the phenocrysts both as sulphide 'blebs' and, apparently, as the crystal lattice. Low Cu contents in genetically related andesites, implying loss of Cu by some process other than crystal fractionation. Hydrothermal alteration of the type normally associated with porphyry-type copper mineralization is extensive in Mount Murray, and may be as extensive in Mount Bosavi. Sulphur-rich hydrothermal fluids are still active on Doma Peaks, and were recently active on Mount Yelia. It is proposed that Cu is mobilized into such late-stage fluids in a high-level magma 'pool' or chamber, and these fluids have the potential, in suitable (reactive) host rocks, to form copper sulphide deposits. The close relationship between volcanoes (particularly those of intermediate composition), associated high-level intrusions, and low-grade copper sulphide deposits is now well known. Many examples exist in other continental margin areas such as the Andes, and the Mount Fubilan deposit, to the west of the Highlands volcanic province, is a local example.

The Papua New Guinea Highlands volcanoes originated by partial melting, triggered by crustal (and lithospheric?) warping in the late Pliocene, of the lower parts of the lithosphere. During the Cretaceous episode of volcanism, fluids from the subducted slab enriched the lower parts of the overlying lithosphere in water and other volatile and incompatible components (e.g. K, Rb, Ba). The amount and extent (particularly upward penetration into the lithosphere) of this modification decreased southward over deeper, hotter, and more depleted parts of the subducted slab, and as the slab became detached and was overridden. Because of the greater degree of chemical modification, particularly added water and added heat-producing radioactive isotopes (e.g. K, U, Th), the more northerly parts of the modified lithosphere were more gravitationally unstable to shallower depths than the southerly parts, and more inclined to initiate diapirism and, eventually, partial melting. Diapirism and consequent partial melting did occur as a result of, or may have been at least partly responsible for, the late Pliocene upwarping movements. Partial melting was most extensive and shallowest in the north where the lithosphere was most modified (hence oversaturated incompatible-rich magmas), and least extensive and deepest in the less modified southerly parts of the lithosphere (hence transitional and undersaturated magmas poorer in incompatible elements).

Other Volcanoes by R.W. Johnson

The following accounts are of different aspects of continuing work of the geology and petrology of late Cainozoic volcanoes in Papua New Guinea.

Volcanic rock associations at convergent plate boundaries: Re-appraisal of the concept using case histories from PNG (R.W. Johnson, D.E. Mackenzie, and I.E.M. Smith (ANU): Three volcanic rock associations, identified by the geographic acronyms TLTF, MRB, and SBS, can be recognised in seven Late Cainozoic provinces at convergent plate boundaries in Papua New Guinea. These associations are distinguished on a variation diagram showing Differentiation Index relative to normative nepheline or to normative quartz plus the silica of normative hypersthene; this diagram serves as the basis for a preferred scheme of volcanic rock nomenclature for arc-trench systems. Rocks of the TLTF group constitute a dominantly 'alkaline' (ne-normative) association. In contrast, the MRB and SBS groups do not correspond with any of the associations widely postulated for other circumoceanic regions. 'Calcalkaline'-type rocks, for example, are found in both associations: in the MRB group they form compositional continua with 'shoshonitic' rocks, and in the SBS group they form continua with 'tholeiitic' ones. It is suggested that circumoceanic rocks should not be classified into artificial, world-wide, 'standard' associtions; a more meaningful method is to identify associations on a regional basis. However, the most useful procedure would be if the same ranges of rock compositions and relative abundances of rock types in individual tectonic provinces could be correlated with specific geodynamic features or source-region compositions. These correlations may lead to the recognition of natural rock associations on a world-wide basis.

Late Cainozoic volcanic magmas associated with past and present arc-trench systems in PNG (R.W. Johnson, D.E. Mackenzie, and I.E. Smith (ANU)): The Late Cainozoic volcanoes of Papua New Guinea may be divided into nine distinct volcanic provinces, seven of which are related to arc-trench systems. Four of the arc-trench provinces are associated with present-day subduction at currently active convergent plate boundaries. In contrast, there is insufficient evidence from the three other arc-trench-type provinces that the Late Cainozoic volcanism is related to Late Cainozoic subduction. Most rocks from these three provinces have greater LIL-element contents and higher $^{87}Sr/^{86}Sr$ values, than do those of the other provinces; their chondrite-normalized REE patterns are nearly straight, with La_N/Yb_N values of about 7. The primary magmas of the three provinces are thought to have originated in mantle lithosphere (garnet peridotite) which had been chemically modified in the Early Cainozoic, or Late Mesozoic, by slab-derived fluids rich in water and LIL elements. In the Late Cainozoic, this chemically modified lithosphere may have become involved in new tectonic regimes which favoured anatexis of the hydrated peridotite, but which did not involve subduction.

Potassium variation across the New Britain volcanic arc (R.W. Johnson): Late Cainozoic volcanoes of the New Britain island arc overlie an inclined Benioff zone that extends to a depth of at least 580 km. The rocks are tholeiitic basalt, andesite, dacite, and rhyolite. Unlike many other examples of island arcs described in the literature, K_2O contents in rocks with the same SiO_2 content do not increase progressively as depth, h, to the New Britain Benioff zone increases. The most complex relationships between K_2O, SiO_2, and h are shown by volcanoes overlying the deeper part of the Benioff zone. In these, the K_2O contents of rocks containing more than about 60 percent SiO_2, decrease as depth to the Benioff zone increases. The New Britain volcanic arc provides a striking exception to the generalisation that K-h relationships are essentially similar in all island arcs.

Distribution and major-element chemistry of Late Cainozoic volcanoes at the southern margin of the Bismarck Sea, PNG (R.W. Johnson): Two Late Cainozoic volcanic arcs can be recognised at the southern margin of the Bismarck Sea, Papua New Guinea. Both arcs provide striking examples of the geodynamic complexity to be expected in regions characterised by small plates whose instantaneous poles of rotation are nearby. A western arc is associated with the boundary between the South Bismarck and Indo-Australian plates. The chemical compositions of its volcanic rocks change along the arc - i.e. in a direction parallel to the strike of a postulated subducted lithospheric slab. These changes can be explained by identifying Late Cainozoic poles of rotation in the northwestern part of mainland Papua New Guinea, and by postulating eastwardly increasing rates of plate convergence. An eastern volcanic arc is associated with the boundary between the South Bismarck and Solomon Sea plates. The volcanoes are arranged in an unusual zig-zag pattern, and the compositions of the volcanic rocks change with increasing depths to the northward-dipping New Britain Benioff zone - i.e., in a direction at right-angles to the strike of the Benioff zone and to the axis of the New Britain submarine trench. The existence of a thrust slice in the northwestern corner of the Solomon Sea is postulated to account for the distribution pattern of the eastern-arc volcanoes.

Investigation of hot gas emissions from Koranga volcano, PNG (C.J. Pigram (GSPNG), R.W. Johnson): Emissions of hot gas (mainly sulphur dioxide and carbon dioxide) took place from a mound in Koranga open cut, near Wau (Morobe province), following a landslide at the end of May, 1967; these were then interpreted by the late G.A.M. Taylor. Rocks of the Holocene volcano, Koranga, are exposed in the open cut. The emissions lasted about three months, and ceased on August 13 after another landslide removed the active mound. During the period of activity, recorded temperatures ranged up to 680°C; no anomalous seismic or tilt phenomena were recorded. The cause of the 1967 activity is not known, but it is thought that the high temperatures and gases may

have been the result of the spontaneous combustion of reactive sulphides and carbonaceous material present in the altered rocks of Koranga volcano.

Stable isotope and chemical studies of furmarolic exhalations and thermal waters, Rabaul caldera, New Britain, PNG: by I.H. Crick

The aim of the project is to (a) obtain an understanding of the origin of fumarolic gases and thermal waters in the Rabaul caldera and (b) to apply this understanding to deriving an origin for the enhanced heavy mineral concentrations found in some of the thermal springs in order to gain more insight into the development of ore deposits formed in volcanic environments.

Work on this project was done jointly with D.C. Green of the University of Queensland and J.R. Hulston of the Institute of Nuclear Sciences, New Zealand, with valuable assistance being given by D.A. Wallace of the Rabaul Volcanological Observatory. Papers on this work were read at the Volcanology and Ore Genesis Conference in London, February 1976, and at the International Conference on Stable Isotopes held in New Zealand in August 1976. A paper containing this work will be published in a special DSIR (NZ) Bulletin early in 1977.

Low-temperature fumarolic exhalations from Tavurvur and Rabalankaia volcanoes and thermal waters in Matupi Harbour and Sulphur Creek, Rabaul Caldera have D/H and O^{18}/O^{16} ratios that indicate a mixed source. They are the result of mixing of local meteoric waters with hot water of marine origin. The stable isotope data are grouped into distinct areas close to the meteoric water line and suggest that the thermal systems away from the shoreline are dominated by meteoric water and that warmed sea water only enters the springs at the shoreline.

These conclusions conflict in part with those drawn from anion ratio and trace metal contents and inferred by previous authors to be consistent with an hypothesis of modified sea-water origin. The chemistry of these acid, mineralised geothermal waters is a reflection of their later, near-surface history and does not necessarily give a correct picture of their ultimate origin. The enhanced Fe, Mn and Zn values of the Matupi springs are a function of the leaching potential of geothermal fluids at elevated temperatures and of the chemistry of the porous rocks through which they pass.

PETROLOGICAL, GEOCHEMICAL, AND GEOCHRONOLOGICAL LABORATORIES

Supervising geologist: K.R. Walker (to June); John Ferguson (after June)

STAFF

Professional Staff: John Ferguson, A.D. Haldane, A.Y. Glikson, R.W. Page, S.E. Smith, L.P. Black, J.W. Sheraton, R.N. England (to Sept.); D.H. McColl (part time), B.I. Cruikshank, D.J. Ellis (study leave) A.G. Rossiter, C.M. Gardner, G.R. Ewers, P.A. Scott.

Technical Staff: M.W. Mahon (to August), T.I. Slezak, T.K. Zapasnik, G.W.R. Barnes, J.G. Pyke, J.C.W. Weekes, K.J. Armstrong, R. Flossman, J.L. Duggan (TTO course), J.L. Fitzsimmons.

Training Technical Officers: J. Purcell, B. Jones (part time) R. Tracy (part time), G. Sparksman (part time), J. Price (part time), D. P'fister (part time).

INTRODUCTION

The projects carried out by the Metalliferous Laboratories during 1976 are classified as follows:

(1) Petrological-geochemical investigations closely associated with BMR regional mapping projects;

(2) Geochronological investigations closely associated with BMR projects;

(3) Regional petrochemical surveys designed to tackle specific problems of base metal distribution and the origin of mineralization;

(4) Regional stream sediment surveys;

(5) Laboratory analytical services;

(6) Geochemical studies carried out in collaboration with non-BMR projects.

Examples of the first category are the Antarctic, Arunta, Mount Isa, Westmoreland, and Duchess projects, most of which involve petrographic, major and minor element classification of rock types and rock units mapped during regional mapping on 1:250 000 or 1:100 000 scale.

The second category includes isotopic age determination of material collected by the geochronologist in liaison with regional mapping surveys. This type of work is essential for correlation between discontinuously exposed and/or structurally separated terrains. Other specialist studies include projects connected with alkaline ultramafic rocks, the Cambrian/Precambrian boundary in western Tasmania, and Elcho Island glauconite dating.

The third type of investigation is a study of the distribution and genesis of ore deposits. Examples of this type include the study of uranium mineralization in the Pine Creek geosyncline the Archaean Warrawoona volcanic group in the Pilbara region, the Tennant Creek mineral field, and the Cullen granite.

Regional stream sediment geochemical surveys carried out within 1:100 000 Sheet areas mapped by BMR is a relatively new type of activity. This work promises to throw light on problems related to the dispersion of elements in addition to the main function of evaluating mineral potentials.

Analytical chemical work, utilizing XRF and AAS equipment, mineralogical analyses by XRD, and thin section and sample preparation constitute the foundation on which all the various work is based. During the year a large amount of material has been prepared and many analyses carried out.

Twenty-five manuscripts have been published, completed or submitted during the past year.

PETROLOGY AND MINERALOGY

ARUNTA GRANULITES STUDY by A.Y. Glikson

Compilation of data for the Anburla 1:100 000 Sheet area and Narwietooma 1:100 000 Sheet area has continued, and 250 thin sections were examined for this purpose and for the purpose of selecting suitable material for chemical analysis.

The granulites examined include orthopyroxene-clinopyroxene labradorite assemblages, garnet-bearing basic granulites, and intermediate to leucocratic granulite and gneiss as concordant veins and segregation bands containing orthopyroxene, garnet, K-feldspar and quartz as essential components. Biotite and amphibole are common in both the basic and the acid granulites. The K-feldspar is mostly sanidine, and commonly occurs as rapakivi-textured porphyroblasts. The leucocratic bands are interpreted in terms of partial melting of the basic host rocks. The reaction orthopyroxene + plagioclase clinopyroxene + garnet can be recognized signifying increased pressure.

MOUNT ISA by A.Y. Glikson

A paper dealing with the geochemistry of the basic volcanics has been prepared (Glikson and Derrick - see Appendix). A further paper has been published (Glikson et al., 1976 - see Appendix), concerning the structural evolution and tectonic setting of the Leichhardt River fault trough.

PILBARA GEOCHEMICAL PROJECT by A.Y. Glikson, A.H. Hickman (GSWA).

Following the collection of about 400 specimens during the 1975 field trip in the Marble Bar area, an examination of these rocks in thin section was undertaken. The collection included amphibolitic metabasalts and metadolerite, chlorite-tremolite high-Mg volcanics, clinopyroxene-bearing quench-textured volcanics (komatiites), amphibole-oligoclase meta-andesite, albite-quartz dacite porphyries, tuffaceous dacitic to rhyolitic volcanics, acid agglomerates, and associated black cherts, carbonates and pelitic sedimentary rocks. About 205 samples were selected for chemical analysis, mostly comprising least-carbonated types, but also about 30-40 carbonated equivalents, for the purpose of studying chemical changes upon alteration.

The samples were crushed and sieved, and fresh chips were visually separated for milling in a chrome-steel vessel. The powders were submitted for XRF (major and minor elements) and AAS analysis along with 16 USGS-standard-calibrated BMR standards. To date, the AAS analyses were carried out, and a completion of the XRF work is anticipated before the end of the year.

Thirty-five samples of amphibolites and carbonated metabasalts from the Talga-Talga Subgroup, submitted by the GSWA, were analysed for major and trace elements. The results have shown marked depletion in alkalies and base metals with carbonatization. The resultant migration of these elements may be of significance in connection with economic mineralization.

ARCHAEAN TECTONIC-GEOCHEMICAL STUDIES by A.Y. Glikson

The analyses of 22 komatiite samples collected in 1972 in the Barberton Mountain Land, Transvaal, South Africa, has been carried out, and the interpretation of the results has commenced.

The concepts developed in the published papers are summarised as follows:

(1) In each Lower Precambrian granite-greenstone terrain at least two greenstone assemblages are recognised. The early assemblage is dominated by ultramafic-mafic volcanic rocks, some acid volcanics, and chemical sedi-

ments; these rocks predate the isotopically oldest granites with which they are associated. The younger greenstone assemblage may contain a higher abundance of mafic to acid volcanics, and clastic sediments; these rocks postdate the isotopically earliest granites.

(2) It is inferred, in agreement with D.H. Green's idea (1972), that the early ultramafic-mafic greenstones date back to and could have originated by meteorite impacts about 4.1-3.8 b.y. ago.

(3) Archaean granulite-gneiss terrains are considered to represent infra-crustal roots of granite-greenstone systems. The best example of a transition of this type occurs in the Indian Shield, and it is suggested on the basis of BMR geophysical data that this may also be the case in the Yilgarn Shield.

(4) The geochemistry and isotopic characteristics of the oldest granites of granite-greenstone terrains indicate their origin to be by partial melting of basic mantle-derived parental rocks.

A brief paper: 'Early Precambrian ultramafic-mafic volcanics: Relic oceanic crust or terrestrial maria?' summing up the conclusions has been published.

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

The geochemistry of metamorphic and igneous rocks from MacRobertson Land was investigated to complement reconnaissance geological mapping of the area, and, in particular, to help elucidate the origin and metamorphic history of the various rock types. About 200 samples, including high grade felsic and mafic gneisses and both granitic and basaltic igneous rocks, were analysed for 10 major and 17 trace elements by X-ray fluorescence and atomic absorption techniques.

Felsic Gneisses. Amphibolite facies biotite ± garnet gneisses from the southern Prince Charles Mountains are predominantly of approximate granitic composition and were probably derived by metamorphism of greywacke-type sediments or acid volcanics. Biotite ± ferrohastingsite gneisses have particularly high Y, Zr, La, Ce and, in some cases, Nb and Ba contents, and low Niggli mg values. Like the ferrohastingsite-bearing granitic rocks (see below), the latter rocks are diopside-normative and are therefore thought to be of intrusive igneous origin.

Many of the granulite facies orthopyroxene-garnet gneisses from the northern Prince Charles Mountains and Mawson Coast are relatively silica or potash-rich, granitic compositions

being much less common. Relatively sodic, diopside-normative equivalents of the ferrohastingsite gneisses of the southern Prince Charles Mountains appear to be absent. The higher-grade terrains have presumably been depleted in rocks of granitic composition by partial melting, and tend to be composed of more refractory, residual materials, although there may well have been original differences in composition. They also show greater depletion in U and have higher Th/U ratios.

Mafic Gneisses. Amphibolites from the southern Prince Charles Mountains are generally similar in composition to the high-Ti tholeiite dykes (see below), although there is more variation. Those from Mount Menzies are anomalously low in Ti, Fe, P, Y, Zr and Nb, and were possibly derived from volcanogenic sediments. Mafic pyroxene granulites from the northern Prince Charles Mountains and Mawson Coast are even more variable in composition. Most appear to be of tholeiitic igneous origin, but some are probably metamorphosed sediments (calc-silicates or basic tuffs) or the refractory residues of anatexis. There is some evidence for enrichment in K, Rb, and possibly other elements during metamorphism, but in most cases the chemical changes were not great.

Mawson Charnockite. The hypersthene granites of the Mawson Coast (the Mawson Charnockite) are characterized by extreme K-enrichment, as shown by their trend on a normative Ab-Or-An diagram. They differ from more typical granitic rocks in their considerably higher mafic (hypersthene) and calcic plagioclase contents. These unusual chemical features appear to be typical of charnockites in general, and a two-stage model is proposed for the genesis of such rocks. Initial melting of sialic crustal rocks under "wet" conditions would produce granitic liquids and a variety of syenitic or tonalitic residues, depending on source rock composition. Further melting of quartz-syenitic residues under dry granulite facies conditions, at greater depths in the crust, would produce potassic melts, and the retention of variable proportions of the more refractory phases (hypersthene and calcic plagioclase) as xenocrysts in the magma could account for the observed chemical variations in the Mawson Charnockite. Hypersthene tonalites (enderbites) could be derived in similar fashion by melting of tonalitic residues.

Other Granitic Intrusives. Foliated ferrohastingsite-biotite granites and adamellites from the Mount Stinear area, with relatively high K, Y, Zr, Nb, La, Ce and, to some extent, Rb and Ba contents and low Niggli mg values, bear some chemical similarity to the Archaean augen gneiss (probably of intrusive origin) of Mount Bayliss. Most are diopside-normative, suggesting an origin by anatexis of igneous (possibly volcanic) rocks. The possibly Archaean biotite granites of Mounts Ruker and Rymill are strongly fractionated, with low K/Rb and Ba/Rb and high Rb/Sr ratios, and are corundum normative. An early Palaeozoic biotite granite from the Mawson Escarpment is also strongly fractionated, but the widespread granitic veins of the same age are mostly of relatively sodic composition.

Mafic Dykes. Mafic dykes of several types occur in the Prince Charles Mountains. Magnophorite-bearing basalts from Mount Bayliss belong to a rare suite of ultra-potassic subvolcanic and volcanic rocks, and are characterized by very high Ti, K, P, F, Rb, Sr and Zr, and low Al and Na. Olivine-leucite basalts from Manning Massif are also enriched in K, Na, P and incompatible elements, but to a lesser extent than the magnophorite-bearing rocks. Nepheline-normative alkali olivine basalts are found elsewhere in the northern Prince Charles Mountains. Tholeiite dykes (mostly amphibolized) appear to be confined to the southern Prince Charles Mountains, although some of the mafic granulites found farther north may be their metamorphosed equivalents (see above). Most are slightly quartz normative (although an olivine basalt dyke crops out at Mount Rymill), and all have much lower Nb/Y ratios (0.3) than the alkali basalts. At least two types of tholeiite, of uncertain but probably Precambrian age, have been recognized - a high-Ti group (1.7-3.2 percent TiO_2) and a low-Ti group (0.7-1.1 percent TiO_2). The former contain more Fe, K, P, and most trace elements, but less Al, Cr and Ni. The tholeiites do not show very strong chemical affinities with either modern oceanic or continental basalts. The high-Ti group is more comparable with continental basalts, whereas the low-Ti group has some affinities (relatively high Cr and Ni, and low incompatible elements) with marginal basin basalts.

URANIUM MINERALISATION, PINE CREEK GEOSYNCLINE, NT by John Ferguson

Recent mapping by BMR field parties and numerous exploration companies has led to a better understanding of the geology of the Pine Creek Geosyncline. Mining and detailed exploration in this area has also contributed abundant direct information on uranium deposits. All this information is the basis for a broad petrochemical investigation of rocks and minerals aimed at recognizing the controls of the uranium mineralisation.

Sediments and crystalline rocks ranging in age from Archaean to Middle Proterozoic are being petrographically investigated and chemically analysed in order to locate the provenance area of the uranium and establish the distribution and if possible, the correlation of elements. Stable isotope determinations of C, O, and S are being made on coexisting sulphides and/or carbonates and/or graphite from the uranium mineralised areas. From this study it is hoped to establish the temperature of formation and the palaeo-environmental conditions of the uranium mineralisation.

An informal grouping, of three organisations, known as the 'Pine Creek Geosyncline: Uranium Study Group' was formed to promote geological investigation of uranium mineralisation within the Geosyncline. The three members of this group are J.C. Rown-

tree, Pancontinental Mining Limited; G.H. Taylor, CSIRO; and Ferguson as the BMR representative. It is hoped that an International Uranium Conference, dealing with the Lower Proterozoic deposits, be held in Sydney in the latter half of 1978. Tentative planning includes publication of a Proceedings of this Conference.

ALKALINE ULTRAMAFIC ROCK PROJECT by John Ferguson, L.P. Black, D.J. Ellis, R.N. England, J.W. Sheraton and K.R. Walker

This project entails the study of kimberlites, carbonatites and alkaline ultramafic rocks associated in space and time in eastern Australia. Preliminary isotopic age dating techniques indicate different ages for these intrusions. Those occurring in South Australia give a Jurassic age; the northwest New South Wales intrusives are of Permian age and in southeastern New South Wales they postdate the Tertiary volcanics and may be as young as Quaternary. Deep-seated crustal inclusions found in these diatremes include two-pyroxene granulites and eclogites which were dated at approximately 600 m.y. Upper mantle nodules include lherzolites containing aluminous spinel and garnet-bearing varieties. One inclusion contains the assemblage, Al-spinel + garnet + orthopyroxene + clinopyroxene + olivine. This is the first record of a peridotite nodule containing garnet + spinel in equilibrium. The mineralogy of this inclusion represents an assemblage that equilibrated on the quasi-univariant boundary separating the spinel and garnet lherzolite fields encountered in the upper mantle. Temperature and pressure estimates indicate an abnormally high geothermal gradient in the Late Tertiary or Quaternary in southeastern New South Wales - exceeding the average oceanic geotherm. The present-day projection of the geothermal gradient in the general area has been estimated from heat flow and radiogenic heat measurements and is very similar to that predicted by the equilibrium assemblage of this lherzolite nodule. It seems highly probable that the nodule described represented a sample of the perturbed steady-state geotherm generated during Tertiary times and continuing to the present day. Compared with the average shield geotherm the abnormally high geotherm encountered here intersects the graphite-diamond stability curve at considerably higher temperature and pressure, making the prospect of finding diamondiferous kimberlites of Cainozoic age highly improbable.

GRANITES AND ACID VOLCANICS, WESTMORELAND AREA, QLD AND NT by C.M. Gardner.

The Record 'Precambrian geology of the Westmoreland Region, Northern Australia Part III. Nicholson Granite Complex and Murphy Metamorphics' is nearly complete.

INSTRUMENT LABORATORIES AND SUPPORTING FACILITIES

Electron Probe Microanalyser. The electron probe microanalyser and the attached X-ray energy dispersive system have remained largely unused during the year because of the problems with interfacing the equipment with BMR's central computer and in the development of appropriate software necessary for full operation. However, the equipment has been used for many routine qualitative mineral identifications during the year.

X-ray diffraction laboratory (Barnes). More than 1200 samples were analysed in the X-ray diffraction laboratory. Ninety percent of the total work load was devoted to six BMR projects:

> South Australian lake sediment mineralogy (P.J. Cook & J.B. Colwell), 670 samples; Baas Becking (CSIRO) experimental carbonate mineralogy (B. Bubela, P.J. Davies & Jim Ferguson), 124 samples; Baas Becking sulphur isotope studies (T.H. Donnelly), 94 samples; various projects (John Ferguson), 66 samples; Petroleum Technology kerogen research (D.M. McKirdy & Z. Horvath), 51 samples, and the museum mineral collections (D.H. McColl), 44 samples.

A thermal printer and interfacing card have been ordered. The installation and computer link to the HP 2100 should be effected early in 1977. With this complete, the XRD system will be fully automated.

Thin section laboratory (Flossman). Eight hundred and seventy-six thin sections, 212 polished thin sections, 130 polished grain mounts and 48 polished sections were prepared.

GEOCHEMISTRY

REGIONAL STREAM SEDIMENT SURVEYS, QLD AND N.T. by A.G. Rossiter & P.A. Scott.

STAFF: A.G. Rossiter, P.A. Scott, K.J. Armstrong, D.J. Gregg, B. Jones (part-time), R.M. Tracey (part-time).

The regional stream-sediment geochemical surveys undertaken by BMR are designed to study the distribution and concentration of elements in a region and thereby to delineate broad areas where future detailed exploration should be concentrated. To date the following 1:100 000 Sheet areas in north western Queensland have been sampled: Forsayth (1974), Seigal and Hedley's Creek (1975), Gilberton and Georgetown (1976).

Samples sieved to minus 180 microns (85 mesh BBS) as well as heavy-mineral concentrates are collected at a density of about one sample per 2 sq. km. The sieved samples are analysed for beryllium, chromium, cobalt, copper, iron, lithium, magnesium, nickel, silver, and zinc by atomic adsorption spectrophotometry and for arsenic, barium, bismuth, cerium, flourine, lead, niobium, rubidium, sulphur, thorium, tin, tungsten, uranium, and yttrium by X-ray fluorescence spectrometry. Heavy-mineral concentrates are examined under the microscope and analysed semi-quantitatively for a large number of elements by optical emission spectroscopy.

Much of 1976 has been spent developing a computer-based system for interpretation and presentation of the data gathered by surveys of this type. The interpretation side of the system includes information storage and retrieval (INFOL) and programs for plotting probability cumulative frequency diagrams and calculating Spearman rank correlation coefficients. Presentation of the data is in the form of maps depicting sample localities with a pre symbol at each point indicating the concentration in parts per million for three elements. The sample localities and analytical data and symbols are mechanically superimposed on a National Mapping 1:100 000 topographic base using a digitiser and flat-bed plotter. The map legend is added manually.

Georgetown area

During the 1976 field season stream sediments were collected from a total of about 2400 localities on the Gilberton and Georgetown 1:100 000 Sheet areas. In addition, follow-up stream-sediment and soil sampling was carried out around one tin anomaly and three uranium anomalies delineated during the 1974 Forsayth survey.

Geochemical maps of the Forsayth 1:100 000 Sheet area should be available early in 1977. All field and analytical data for the sheet have been transferred to punch cards and sample localities and intended sample positions have been digitised.

Analytical work on the Gilberton and Georgetown samples will commence shortly and geochemical maps for these sheets should be published late in 1978.

Westmoreland area

Analysis of the Seigal and Hedleys Creek 1:100 000 Sheet samples is about two-thirds completed and already some interesting anomalies have emerged. Several uranium anomalies in the northwest corner of the Hedleys Creek Sheet area have been followed up by a company holding an Authority to Prospect in the area. An anomaly in the Seigal Sheet area referred to in last year's Annual Summary was investigated in greater detail during 1976 (see below).

It is anticipated that all the Seigal and Hedley's Creek geochemical maps will be available in 1977/78.

Una May Anomaly, Seigal 1:100 000 Sheet area, N.T. by A.G. Rossiter.

The Una May anomaly was discovered during the 1975 Seigal stream-sediment survey (see last year's Annual Summary). Since then geological mapping and more detailed stream-sediment and soil sampling have been carried out around the prospect.

Geological mapping has disclosed a small (2 km x 1 km) stock of white medium-grained granite intruding fine-to medium grained pink granite. Both rock types presumably belong to the Carpentarian Nicholson Granite Complex. Surrounding the stock is a zone of greisenised veins locally with malachite staining. The highest copper values recorded in soils (up to 1180 ppm) are associated with this zone. The greisens are not extensive enough and the copper values too low to make the anomaly an attractive exploration target.

Of greater economic interest is the northern part of the stock itself where soil values exceeding 20 parts per million uranium occur over an area of more than 0.5 sq. km. The 20 ppm contour appears to roughly co-incide with a ring fracture containing greisen and rhyolite veins. At one point on the ring fracture altered rock contains partly replaced sulphides and what appears to be yellow secondary uranium minerals.

CULLEN GRANITE PROJECT, NT by G.R. Ewers and P.A. Scott

In mid-1975, the BMR in conjunction with the Northern Territory Geological Survey undertook an investigation of the geochemistry of the Cullen Granite. The main objectives of the study were to provide basic information on the geochemistry of the Cullen Granite, including the relationships between the various phases, and to try to establish the relationship between the geochemistry of the granite and mineralisation contained within the granite and surrounding sedimentary rocks.

The results confirm the presence of the five granite phases identified by Walpole et al. (BMR Bulletin 82). They also demonstrate that one of these phases is more highly fractionated (higher SiO_2; lower TiO_2, Al_2O_3, total Fe, MgO, CaO, P_2O_5, V, Sr, Ba, Zr, Ce and La) than the rest. This finding supports the earlier conclusion, based on field observations, that this was a later intrusive phase of the granite.

Uranium concentrations average 9.3 ppm in the Cullen Granite and in two areas are nearly 30 ppm. One of these areas can be correlated with minor secondary uranium mineralisation within the granite while the other is uncorrelated. The data

also indicate that anomalous W and Cu values in several areas may be related to mineralisation in nearby sediments. Tin concentrations are uniformly low throughout the granite (averaging 2 ppm) despite the ubiquitous nature of tin mineralization in adjacent sediments.

It is anticipated that this project will be completed and a Record produced towards the end of 1976.

GEOCHEMISTRY OF THE TENNANT CREEK GOLDFIELD, NT by S.E. Smith and A.D. Haldane

Silicate Rocks

The available chemical data on the Warramunga sediments was reviewed with respect to major and trace element losses induced by weathering and the frequency of anomalous trace element values. The most notable consistent loss of major elements occurs for magnesium and sodium, whilst potassium remains unchanged. For the trace elements only zinc, cobalt, nickel and manganese show reduced values in the weathered zone. Barium, chromium, beryllium, zirconium and vanadium remain unaffected whereas copper and lead show enhancement in the weathered zone. There is no evidence of intensive leaching of trace elements from the weathered zone.

With the exclusion of manganese the only elements of those studied to show anomalous values are copper, lead, zinc, cobalt and nickel all of which are associated with the mineralization. From a total of 311 samples of Warramunga sediments there are 30 anomalous values for copper, 3 for lead, 6 for zinc, 12 for cobalt and 17 for nickel. These are all considered to be related to the sulphide mineralization and indicate that copper is the most efficient element to use in geochemical exploration of the Warramunga sediments.

Of 168 samples of granite and porphyry analysed, only one porphyry sample from the contact with a lamprophyre contained anomalous copper and cobalt - otherwise these rocks show little of interest in their trace element content.

Surface Ironstones

The surface ironstone bodies are dominantly hematite, with quartz, and jasper in varying proportions. The composition of the ironstones sampled ranges from Fe_2O_3 100 percent, SiO_2 0 percent through to Fe_2O_3 5 percent, SiO_2 95 percent. The only other major component commonly present is aluminia with values up to 2 percent in some weathered specimens as high as 4 percent.

The phosphorus content is usually 0.1 percent P_2O_5 but some samples contain up to 1 percent P_2O_5. Similarly the manganese content is typically low (200 ppm) though values to 1000 ppm

are not uncommon. One sample contained over 38 percent Mn and though this sample could hardly be classed as an ironstone it was taken from an outcrop that graded into ironstone. Three samples were taken from this outcrop over a distance of 30 metres and their major components were:

	Fe_2O_3 percent	SiO_2 percent	Al_2O_3 percent	Mn percent
Sample 1	4.92	13.98	6.56	38.8
Sample 2	58.85	9.95	2.33	0.44
Sample 3	62.94	6.04	2.57	0.03

Other elements whose values exceeded the 0.1 percent level at times were TiO_2, MgO, CaO, K_2O, Pb, Bi, Zn, Mo, and Cu. Of these TiO_2, MgO, CaO, and K_2O appear to be of little interest as does nickel and chromium which are usually 20 ppm. A summary of the results of the other elements is presented in Table M2. Though bismuth and lead produce the highest absolute values, 'anomalous' values of molybdenum and copper occur more commonly. Anomalous values for bismuth, lead, molybdenum and copper appear to be widespread whereas zinc appears to be more restricted to the Mt Samuel-Eldorado area.

TABLE M2 Summary of minor element values in surface ironstones.

Element	Most frequent values (ppm)	Frequency of anomalous values* (percent)	Highest Values (ppm)
Bi	30	10	5000
Cu	30	20	2000
Pb	30	10	5000
Mo	30	30	1300
Co	30	6	500
Zn	30	7	1800
Ag	3	0.8	31
Be	3	5	25

* Anomalous values are those values exceeding 5 ppm for Ag and Be, and exceeding 50 ppm for the other elements.

Magnetite Bodies

The main minerals in the magnetite bodies are magnetite, hematite, quartz, chlorite and talc. In the samples collected the range of iron values is 25-71 percent Fe (49 percent of values are greater than 60 percent Fe) and the range of silica values is 0-65 percent (68 percent of the values are less than 10 percent SiO_2). Aluminium and magnesium are also commonly present with Al_2O_3 values to 8 percent (though 75 percent of the values are less than 1 percent Al_2O_3) and MgO values to 10 percent (with 63 percent of the values less than 1 percent MgO). The phosphorous content is as high as 0.5 percent. Manganese is typically low (200 ppm) but there are some high values (to 0.4 percent). Calcium, potassium and titanium values are all low.

A summary of the other elements of interest is given in Table M3. The higher frequency of 'anomalous' values in magnetites relative to surface ironstones could be expected because the magnetites sampled were the targets of drilling programs, selected for their greater prospectiveness.

Table M3 Summary of minor element values in magnetite bodies.

Element	Most frequent values (ppm)	Frequency of anomalous values* (percent)	Highest values (ppm)
Bi	30	28	9500
Cu	30	50	76000
Pb	30	12	6600
Mo	30	60	5000
Co	30	33	800
Zn	30	33	1000
Ni	30	6	450
Ag	3	6	16
Be	3	30	44

* Anomalous values are those exceeding 5 ppm for Ag and Be, and exceeding 50 ppm for the other elements.

POLLUTION STUDIES IN THE MOLONGLO RIVER, ACT by A.D. Haldane

Remedial measures recommended by the joint Government Technical Committee on Mine Waste Pollution of the Molonglo commenced at Captains Flat with the award of the contract for the work to Cleary Bros. in January. Construction work is well advanced and should be completed by the end of the year. As a result the Bureau's involvement has virtually ceased. Testing of samples collected by the Department of Construction from within the ACT continued throughout the year as a precautionary measure. No abnormal results were recorded and it is anticipated that the remedial work will effectively control pollution of the river by the mine waste at Captains Flat.

ANALYTICAL LABORATORIES AND SUPPORTING FACILITIES by B.I. Cruikshank.

STAFF: B.I. Cruikshank, G.R. Ewers, J.G. Pyke, T.I. Slezak, J.C. Weekes, J.L. Fitzsimmons, K.H. Ellingsen.

The Chemical Laboratory continued to provide analytical support for a number of projects carried over from the previous year, these being the Westmoreland geochemical survey, the Georgetown geochemical survey and Antarctic geochemistry. New work associated with projects undertaken by members of the Geochemical and Petrological Groups included Alligator River geochemistry, Arunta/Pilbara geochemistry and Cullen Granite geochemistry. Although these projects provided the bulk of samples analysed in the laboratory, some 900 samples from other projects in the Geological and Geophysical Branches were analysed as resources permitted.

The benefits of instrument/computer interfacing for on-line data processing were amply demonstrated with a record 5840 samples completed or partly completed for a total of 92 000 element determinations by the laboratory's X-ray fluorescence and atomic absorption instruments.

X-ray fluorescence spectrometry

The laboratory now has 2 spectrometers in operation, a new Philips PW1450 and a rather elderly PW1210. This year 524 samples were analysed for major elements (5240 element determinations) including 256 from Alligator River, 148 from the Cullen Granite and 58 from Arunta/Pilbara.

Trace elements were determined on 4,350 samples (56,700 element determinations) including 1,910 from Westmoreland, 1,320 from Georgetown, 256 from Alligator River, 148 from the Cullen Granite and 64 from Antarctica.

Atomic absorption spectrophotometry

The laboratory's Varian AA-6 analysed 4150 samples (30 300 element determinations) including 2870 from Westmoreland, 278 from Georgetown, 256 from Alligator River, 251 from Arunta/ Pilbara, 148 from the Cullen Granite and 60 from Antarctica.

Optical emission spectrography

Some 360 samples were qualitatively scanned using the Hilger Large Quartz spectrograph.

Miscellaneous Determinations

The laboratory also analysed 246 samples for FeO (236 from Alligator River), 78 Molonglo River water samples and 12 Lake George water samples.

GEOCHRONOLOGY

STAFF: R.W. Page, L.P. Black, T.K. Zapasnik, M.W. Mahon (resigned August) and J.L. Duggan (transferred to T.T.O. in March).

During the past year the Geochronology Group continued to successfully employ Rb-Sr dating techniques on several important studies in the Northern Territory, Queensland, Tasmania and New South Wales. In addition, in the Mount Isa Precambrian project, major advances were made by use of the U-Pb zircon approach while Page was on an A.P.S. Postgraduate Scholarship at the Carnegie Institution of Washington. All of these studies have been collaborative efforts with other BMR geologists, and geologists from Northern Territory Geological Survey, Queensland Geological Survey, Tasmanian Geological Survey, New South Wales Geological Survey, Macquarie University, and James Cook University.

Over 1300 solid source (on Nuclide, MS - X, and Carnegie Institution machines) mass spectrometer runs were carried out during the past year, and all the data were reduced with the aid of on-line computer facilities. With the help of ANU personnel, cleaning, painting, and other improvements (installation of clean air work stations) were made to the ANU "rubidium laboratory" so that U-Pb zircon analyses can now be undertaken. For these and other facilities it is appropriate to acknowledge the continued cooperation and assistance from the Director and Staff of the Research School of Earth Sciences.

Mount Isa Project by R.W. Page

Wide-ranging Rb-Sr isotopic dating work in the Mount Isa-Cloncurry area reported in previous annual reports was this year mainly restricted to further detailed study by U-Pb zircon techniques of the sequence of acid volcanic rocks and intrusive granitic rocks in the basement succession. All of these igneous rocks are slightly altered as a result of burial metamorphism or some other low-grade regional metamorphism. Recent Rb-Sr measurements on nine separated micas from these rocks give a minimum age for this metamorphism of 1450 to 1500 m.y., in broad agreement with previously published K-Ar and Rb-Sr mica ages on other units in the region. The Rb-Sr total rock isochron studies of the volcanic sequences had given somewhat spurious results, some of which were not consistent with geological interpretations. Recently this general problem has been alluded to by several workers in other parts of the world. It is now not uncommon to find that application of the Rb-Sr technique to slightly altered igneous rocks, especially acid volcanic rocks, results in apparently good isochrons that are some 10 to 15 percent too young. Apparently minor mineralogical changes can cause drastic isotopic disturbance in the Rb-Sr system. For these reasons, zircons have been separated and analysed from three different acid volcanic units (Leichhardt Metamorphics, Argylla Formation, Carters Bore Rhyolite) and two intrusive granitic bodies (Kalkadoon Granite, Wonga Granite) all earlier studied by Rb-Sr total rock procedures.

Zircon fractions from three felsic volcanic rocks from the oldest unit in the Mount Isa basement sequence, the Leichhardt Metamorphics, provide an array of U-Pb data which can be unambiguously interpreted to give an age of 1868 $\pm$ 4 m.y. (1 sigma error) for the crystallization of these zircons. The Kalkadoon Granite which intrudes the Leichhardt Metamorphics but is considered to be comagmatic with volcanic rocks in it, yields suites of zircons whose pooled U-Pb age (1862 $\pm$ 25 m.y.) is in excellent accord with the geological evidence. Uranium-lead ages in the younger Argylla Formation rhyolites are 1782 + 12 m.y., and this unit is cut by the Wonga Granite which gives a U-Pb zircon age of 1671 $\pm$ 8 m.y. All of these zircon age measurements are in accord with the geology. The precision of the U-Pb zircon systematics allows us to demonstrate that part of this Precambrian felsic volcanic pile (Leichhardt Metamorphics) was cut by its intrusive equivalents during a time interval of perhaps only a few million years, comparable with that observed in more modern volcanic arcs. Acquisition of the independent and consistent zircon data also enables us to objectively examine the Rb-Sr data which in most cases gives ages about 10 percent too young. As the Rb-Sr ages on the units concerned range from 1575 to 1700 m.y., it is difficult to envisage these young Rb-Sr ages as a result of a single regional metamorphic event alone. It appears necessary then to invoke some additional regional, but non-synchronous (continuous)

alteration process, such as ground-water circulation, which could have caused Rb, Sr exchange and open-system behaviour of the total rock systems. The 'events' dated by the sub-linear arrays of Rb-Sr data would in this model approximately correspond to the different times of cessation of the mild hydrothermal leaching and exchange within the various units concerned.

Rum Jungle-Alligator River Project by R.W. Page

Semi-detailed Rb-Sr analytical work has been carried out on granites and gneisses in parts of the Rum Jungle and Waterhouse Complexes. In particular, structureless granitic bodies that intrude the Complexes, and that were postulated by Stephanson and Johnson (1976) to be Carpentarian in age, have been isotopically examined. The isotopic data show that these supposedly younger, "diapirically intruded" bodies have no characteristics that would distinguish them from the remainder of the Complexes - they lie on the same late Archaean-early Proterozoic isochrons as the majority of the rocks in the Complexes. In the western part of the Rum Jungle Complex such an isochron with an age of 2400 $\pm$ 74 m.y. (95 percent error) and initial $^{87}Sr/^{86}Sr$ of 0.706 $\pm$ 0.002 has been established. Leucogranites in the northeasterstatistically different) age of 2347 $\pm$ 39 m.y.

For the Waterhouse Complex there is not yet sufficient data to define an independent Rb-Sr isochron. The coarse porphyritic granites and some microgranites from three sample sites broadly conform to a 2400 m.y. isochron, whereas garnet gneisses and nearby foliated microgranites at another locality give a 1755 $\pm$ 26 m.y. age with a high initial $^{87}Sr/^{86}Sr$ of 0.780 $\pm$ 0.009. These latter rocks have evidently completely responded to the Carpentarian regional metamorphic event which is so widespread in the Pine Creek Geosyncline.

Tennant Creek Block by L.P. Black

Thirty-five isotopic analyses for both Rb and Sr were made during the year. These show that the Bernborough Volcanics are about 1800 m.y. or older, and that at least part of the Cabbage Gum Granite is approximately 1500 m.y. old. Lode material from some of the big mines yield muscovite ages which are older than any of the indicated granite ages. Current isotopic work in the Tennant Creek area is now complete and writing-up is proceeding.

Arunta Block by L.P. Black

A total of 109 rocks and minerals were mass-spectrometrically analysed for Rb and Sr. Volcanic and sedimentary units from the Reynolds Range yield total-rock ages of approximately 1500 m.y., but these could be interpreted as either emplacement or metamorphic ages; the latter seems more probable. Samples of

the Jervois Granite collected during 1975 confirm the previously estimated age of about 1800 m.y. for this unit. Isotopic results for the ultrabasic Mordor Complex indicate emplacement at 1200 m.y. The rather high initial $^{87}Sr/^{86}Sr$ values for the Complex are thought to derive from a heterogeneous upper mantle enriched in Rb and ^{87}Sr. Black is currently writing up this project with P.A. Langworthy.

Alkaline Ultramafic Project by L.P. Black

A total of 27 total-rock and mineral separates have been analysed. Preliminary interpretation of the data suggests that the kimberlites of Eastern Australia were emplaced at different times during the Phanerozoic.

Elcho Island Glauconite Project by L.P. Black

The glauconite samples collected last year confirm the original isotopic analyses of a decade ago. Both K-Ar and Rb-Sr ages agree at about 800 m.y. This is several hundred million years older than the trilobites collected from Elcho Island would suggest. The two most logical explanations would seem to be that these glauconites have a detrital component or there is an unconformity between the glauconite and fossil localities. Glauconites from other areas of Australia such as the Wiso Basin were analysed for supportive information but yielded inconclusive results.

Western Tasmania by L.P. Black

The results of this study are currently being written-up in collaboration with members of the Tasmanian Geological Survey. A total of 93 rocks and minerals from the Mt Read Volcanics were analysed. These yield ages which are generally too young to accord with established stratigraphy. It appears that, as was the case with the Mt Isa district, these rocks are preserving metamorphic rather than emplacement ages.

Herberton-Mt Garnet area by L.P. Black

Sixty-six rocks and minerals were mass-spectrometrically analysed for Rb and Sr during the year. Analysis of the micas from mineralised areas was completed and is currently being written up with D.H. Blake. Some samples of the Featherbed and Nychum Volcanics which were originally analysed a decade ago were remeasured to test for possible contamination of the radiogenic spike at that time. Samples of the Claret Creek Ring Complex apparently indicate that this unit was intruded over a considerable time interval.

Georgetown Inlier by L.P. Black

Considerable emphasis has been placed on this project during the past year, with a total of 198 rocks and minerals being isotopically analysed for Rb and Sr. However, none of the separate sub-projects has yet been completed. Approximately half of the Newcastle Range samples have been analysed and appear to confirm the previously estimated Middle-Upper Carboniferous age. Much of the Forsayth Granite has now been shown to be definitely Precambrian, though different ages, which have not yet been fully resolved, are apparent. One of the major aspects of the Georgetown Inlier study is that of establishing the metamorphic chronology. This work is being done with T. Bell and M. Rubenach of James Cook University and I. Withnall of the Queensland Geological Survey. Preliminary results indicate that the Rb-Sr method will be successful in discerning the separate metamorphic events.

MISCELLANEOUS ACTIVITIES

TECTONICS OF AUSTRALIA

by

K.A. Plumb

STAFF: K.A. Plumb; H.F. Doutch; E. Nicholas, J. Branson.

A 1:10 million-scale draft tectonic map of Australia has been compiled and submitted to the Subcommission for the Tectonic Map of the World, for inclusion into their 1:15 million-scale map of the world.

Four papers describing various aspects of the tectonics of Australia were presented to Symposium 103.3 - The Structure of Australia and Variations in Tectonic Style - of the International Geological Congress. Preliminary drafts of these papers were released as Record 1976/72, and they are now being revised for publication in a special symposium issue of Tectonophysics.

OVERSEAS VISIT: D.H. BLAKE TO THE GEOLOGICAL SURVEY OF CANADA

by

D.H. Blake

In April 1976 D.H. Blake began a 12-month exchange visit with the Precambrian Subdivision, Regional and Economic Division, Geological Survey of Canada, based in Ottawa. In exchange, Dr D.F. Sangster of the Economic Geology Subdivision will spend a year with BMR, based in Canberra, beginning in mid-1977.

Blake spent the field season, from early June to late August 1976, with two field parties mapping Archean metamorphic rocks and Proterozoic cover rocks in the Keewatin District of the North West Territories, between latitudes 62° and 64°N and longitudes 95° and 100°W. He was mainly involved in mapping rocks of the Proterozoic Dubawnt Group, especially their constituent volcanics, about 1725 m.y. old. These are of economic interest as they have some associated uranium and minor copper mineralization. The volcanic rocks comprise subaerial lava flows and pyroclastics, volcaniclastic sediments, local mixed rocks interpreted as hyaloclastites, various high-level intrusives, and vent breccias. The volcanics lie between Dubawnt Group sedimentary rocks; mainly fluvial highly feldspathic sandstone below, and more-quartz rich sandstone that is probably at least partly marine above. Most of the lavas are rich in potassium and are provisionally classified as trachytes and trachyandesites. They generally contain biotite and augite phenocrysts and have alkali feldspar as the dominant groundmass phase. Some rhyolite extrusions are also present. The lavas appear to closely resemble some of the Quaternary potassic lavas of eastern Papua, Papua New Guinea, not only in their petrography but also in their tectonic setting: they were erupted from small volcanic centres situated close to active major faults, mainly on alluvial plains and fans adjacent to highlands of metamorphic rocks. The uranium and copper mineralization within the Dubawnt Group volcanics is confined to narrow fracture zones trending 120°, and consists of chalcopyrite, hematite, pitchblende, and associated secondary minerals in calcite gangue.

GEOLOGICAL SERVICES SECTION

Head of Section: E.K. Carter

GENERAL

by

E.K. Carter

No substantial changes were made to the organization of the Section during the year, but effective staff numbers declined by eight, and wages hands by four, owing to resignations, staff movements and restraints on recruitment.

The 25th International Geological Congress, held in Sydney in August, required a substantial input by practically all members of the Section. The efforts of the Drafting and Map Compilation groups resulted in four major new maps, and several other maps, being available for the Congress.

The Engineering Geology sub-section provided geological services for several major dam and sewer main projects, continued follow-up work in several urban development areas in the Canberra, carried out other investigations of projects and problem areas, maintained hydrogeological and geotechnical data collection and advanced the preparation of several geological and geotechnical maps. Three overseas investigations were carried out.

During the year the Museum became custodian of the outstanding C. Latz collection of Australian and foreign display minerals, donated to the Australian Government. The Curator and staff maintained or provided displays, made collections and assisted visitors throughout the year.

Publication in Paris of the "Australia, General" fascicule of the International Stratigraphic Lexicon provided a reference to published stratigraphic names to the end of 1968. The stratigraphic nomenclature service to Australian geologists was maintained throughout the year.

ENGINEERING AND ENVIRONMENTAL GEOLOGY

STAFF: E.G. Wilson, G. Jacobson, D.C. Purcell, J.M.M. Furstner, (to 29th October, 1976), G.A.M. Henderson, P.D. Hohnen, P.A. Vanden Broek, P.H. Lang (12th July to 9th September 1976), G. Briscoe (to 8th October 1976), R.C.M. Goldsmith.

Technical Officer: J.R. Kellett; Technical Assistant, A.W. Schuett, 8 - 4 field hands.

GENERAL

Some of the investigations reported below were carried out jointly with the Engineering Geophysics Group with which close liaison was maintained. All seismic surveys referred to, unless

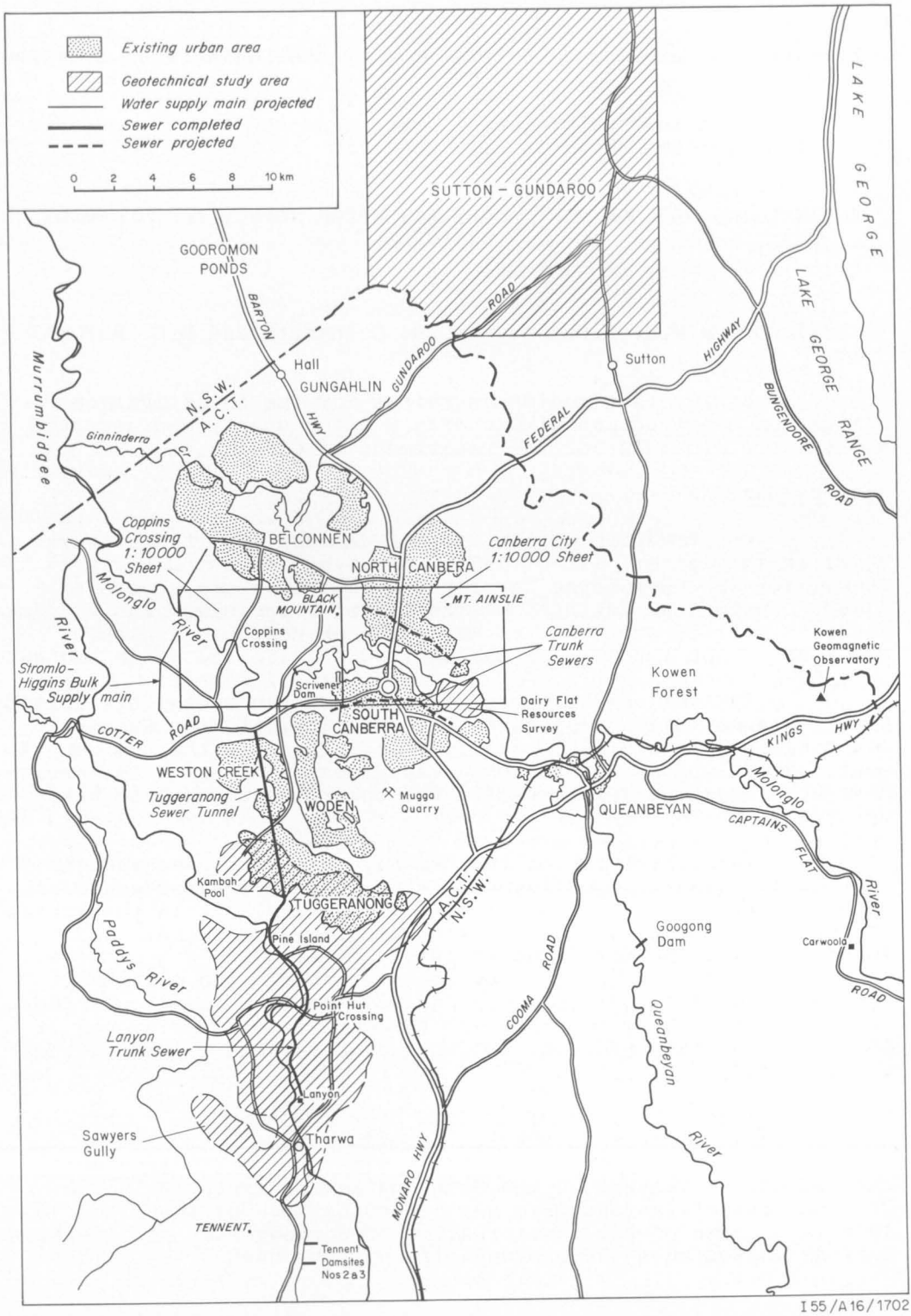


Fig. GS1. Project location map, Canberra and adjacent areas.

otherwise indicated, were carried out by the Engineering Geophysics Group.

Locations of projects in and near the A.C.T. referred to in the text are shown in Fig. G.S. 1.

ENGINEERING GEOLOGY FOR CANBERRA'S WATER SUPPLY AND SEWERAGE SYSTEMS

by

G. Briscoe, J.M.M. Furstner, R.C.M. Goldsmith and D.C. Purcell

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

Googong Dam

Construction of the Googong dam and appurtenant works began in the latter half of 1975. The 6-m diameter diversion tunnel for the Queanbeyan River has been driven and concrete lined. Geological features of the tunnel were logged and a joint analysis carried out. Advice was given on concrete lining of sections of the tunnel; it was decided to line the whole tunnel.

Excavation for the spillway crest and energy dissipation pool was about half complete by October 1976. If the excavated material is suitable as rockfill, it is placed in the dam embankment. Shale and sandstone lenses and sheared zones in the dacite have been rejected for rockfill, and their locations have been delineated.

The abutments for the dam have been stripped and the curtain and blanket grouting completed. Major sheared zones and zones of weathered and fractured rock (particularly in the granite in the left abutment) have had special grout treatment. The foundation for the core zone is partly cleared and a geological log is added to as exposures become available. The embankment was 13 m high on 1 October 1976 and will be 58 m when completed early in 1977. Clay material for the core-zone is being won from colluvial deposits adjacent to the Queanbeyan Fault 1 km to the east.

Tennent Damsite

Investigations of possible alternative damsites were carried out at Tennent on the Gudgenby River, south of Tharwa. Previous investigations were carried out at one of the sites in 1968-1970 for a possible alternative to Googong Dam, but investigations ceased when the Googong site was chosen.

In 1976 investigations were carried out on two additional alternative sites for dams 85 and 100 m high respectively. Geological and geophysical advice concerning the excavation and foundation conditions and the stability of the dam abutments was supplied to the Department of Construction.

Tuggeranong reservoir sites

Fourteen water storage reservoirs are planned for the supply of water to the suburbs of Tuggeranong. Thirty-seven reservoir sites were mapped and investigated using seismic refraction techniques to enable the most suitable sites to be selected. The amount of blasting is an important factor in the selection of alternative sites.

Most of the reservoirs are to be circular concrete tanks which require highly weathered or stronger rock for foundations. Embankment-type reservoirs do not require as strong a foundation material and deeply weathered rock and soil can be mechanically excavated and used to form the embankment.

Sewer mains

The main Tuggeranong Sewer Tunnel was completed in 1975, and investigations for connecting trunk sewers for Tuggeranong to the tunnel were undertaken. Advice was given on ease of excavation and slope stability for cut and cover sewer lines, and assessments were made of tunnelling conditions where a tunnel might be a suitable alternative. Lanyon Trunk Sewer involved the assessment of five alternative routes, a distance of 20 km including 2 km of tunnelling. Some major sewer lines incorporated drop structures to facilitate connection with Tuggeranong Tunnel. About 1 km of seismic traverses were required for these investigations.

Some progress was made in producing the geological completion report on the construction of the Molonglo Valley Interceptor Sewer, and advice was given as required by Department of Construction on the Molonglo Water Quality Control Centre, under construction.

Canberra trunk sewer

Two alternative routes for the replacement of Canberra's trunk sewer are being investigated. Four diamond-drill holes were sunk to investigate shaft sites and additional holes are planned early in 1977.

A summary of the geology of the alternative routes, from near Fyshwick to west of Black Mountain, was prepared for the Department of Construction.

HYDROGEOLOGY

by

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

Cocos Islands groundwater investigation

Groundwater resources were investigated on Home Island, in the Cocos (Keeling) Islands, Indian Ocean, to assess the prospects of developing a reticulated water supply and sewerage system for the settlement there. Home Island is part of the South Keeling atoll and contains a lens of fresh groundwater overlying sea water. Measurements of water-levels in existing wells, and levelling with respect to mean tide-level, indicate that theoretically the freshwater lens is up to 19 m thick, and averages about 15 m over an area of about 30 hectares. Allowing for tidal fluctuations and for periods of drought, the sustainable yield of the aquifer would be about 200 000 litres per day. Recommendations have been made for the development of the aquifer by pumping from infiltration galleries; pumping should reduce the lens thickness by no more than half if salt-water contamination of the aquifer is to be avoided.

Hydrogeology, ACT and environs

Monitoring and maintenance of groundwater observation bores continued in the A.C.T. and environs and the Federal Territory of Jervis Bay. Measurement of water levels at Lake George, New South Wales, continued. Lake Windermere, Jervis Bay, is at an historically high level and Lake George is at the highest level for more than ten years.

A hydrogeological map of the A.C.T. and environs at 1:100 000 scale is being compiled; basic data include bore locations, chemical analyses of groundwaters and geology. A reference has been prepared according to the guidelines of the International Association of Hydrogeologists.

Lanyon drainage investigations

Weekly recording of groundwater levels continued throughout the year, and maps were prepared showing fluctuations in groundwater potentials for the first eighteen months of observations.

Infiltration tests were carried out on typical soils of the basins to enable groundwater recharge from rainfall to be calculated and to determine the time lag between rainfall and piezometer response.

Correlation coefficients between groundwater levels in the alluvial aquifers and those in the fractured rock aquifer were found to exceed 0.85 in areas where no extraneous influences were present. This close correlation supports the theory of hydraulic connectivity between the two aquifers and in particular established that there is a path along which groundwater moves in the intervening fanglomerate layer. Five diamond-drill holes confirmed a high frequency of open joints in the fanglomerate.

The effect of sequences of rainfall events of differing recurrence intervals on the hydraulic head was calculated for given drain spacings using the one dimensional diffusion equation. The validity of the Dupuit-Forchheimer assumptions were tested by modelling the existing effluent creeks with known values of the hydraulic head throughout the observation period.

GEOLOGY FOR URBAN DEVELOPMENT, A.C.T. & ENVIRONS

by

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

Geological services were provided for urban planning and development projects of the National Capital Development Commission and the Department of Construction.

Canberra 1:10 000 maps

The preparation of engineering geological maps of the ACT at 1:10 000 scale continued. Some amendments and additions were made to the Coppins Crossing Sheet; compilation of the Canberra City Sheet has reached an advanced stage and compilation of the Woden-Weston Creek Sheet is in progress. Field work is in progress on the South Canberra Sheet and some mapping was done on the North Canberra Sheet. Some stratigraphic problems remain, owing to the complicated structure of the area. Useful structural information was gained from the mapping of the Ryan sewer tunnel on the Coppins Crossing Sheet. 1:2 500 scale ortho-photo maps have recently become available for some areas covered by the 1:10 000 sheets and are proving useful as field sheets.

Canberra stratigraphic drilling

Several holes were drilled for stratigraphic purposes in the Canberra area, including one at Gooromon Ponds, between Hall and Murrumbateman, NSW. The holes in the Canberra City area were designed to gain information on the succession within the Canberra Group. One hole between the BMR building and Russell Offices intersected a 300-m succession of mainly shale and lime-

stone, probably within the St Johns Church Beds which lie at the top of the Canberra Group. Four other holes to depths of 30 m were also drilled in the St Johns Church Beds, and two holes to 30 and 50 m were drilled in the Turner Mudstone. The hole at Gooromon Ponds was drilled in calcareous sedimentary rocks which are regarded as a southern continuation of the Yass Subgroup. At present the hole has reached a depth of 190 m; the target depth is 300 m.

Tuggeranong urban planning

Geological investigations for urban planning were undertaken at Sawyers Gully and Lanyon in the new town of Tuggeranong, ACT.

Sawyers Gully is a valley near Tharwa, enclosed by hills and with drainage to the southeast via Woolshed Creek. Low-density, broad acre residential development is planned for the valley floor, lower hillslopes and benches on steeper slopes. The main geological constraints on development will be the drainage of swampy areas on the valley floor, the steep slopes surrounding the valley and excavations in areas of rock outcrop. Cemented colluvium which has been observed in a few gullies may cause excavation and drainage problems.

The suburb of Lanyon lies to the east of the Tharwa Road near the intersection with the Point Hut Road. Plans for the urban development of this area are being revised with the emphasis on increase in housing density and development on slopes to the east and north that are steeper than the limit of 1 in 5 that has previously been accepted in Canberra. The investigation enabled constraints on development within the proposed area to be identified as well as the additional constraints of extending the area onto the steeper slopes. The main problems in development of the original area will be the drainage of swampy areas on the valley floor and the stability of cuts and excavations in colluvium. Unconsolidated colluvium will be unstable in steep cuts and excavations, and a cemented colluvium, or fanglomerate, has sand and gravel lenses that are permeable and tend to slump. The cemented colluvium may require blasting for excavation. Development on the steeper slopes will encounter some difficulties in excavation in rock and in stabilizing cuts in the slopes.

Gungahlin urban planning

Seismic and geological investigations have been carried out at the proposed Town Centre and first residential area in Gungahlin. The bedrock is mostly shale which crops out in only a few places and generally shows depths of rippable material of 1.5 to 4 m - assuming a 1200 m/s seismic-velocity limit for rippable material. Many hilltops are capped by volcanic rocks, mainly tuff, in which excavation generally requires the use of explosives.

Depths to fresh bedrock range from 5 m to 30 m, but are generally 10 m to 15 m. Very low velocities were encountered to depths of over 100 m in the Canberra Racecourse area, and may represent either alluvium or in situ weathered rock. Many known and inferred faults through the area have been located by seismic techniques, and other probable faults located.

Sutton/Gundaroo mapping

A field camp was set up west of Gundaroo during December 1975 and January 1976 from which a geological survey of the area between Gundaroo and the ACT border was carried out. The purpose of the mapping was to gain basic geological information for the Canberra 1:100 000 Sheet and for possible future development in the area. Formations similar to those in the Canberra City area are present but the structure in much of the area is less complex. A probable major unconformity within the Silurian, corresponding to the Capital Hill unconformity, was found.

Regional sand and gravel resources

A regional survey of sand and gravel resources in the ACT and environs indicates that supplies of sand and gravel adequate for many years are available in the ACT region. Most sand and gravel is likely to come from the Bungendore area in the foreseeable future, and large deposits of sand and gravel are located along the Murrumbidgee River, near Burrinjuck dam.

The National Capital Development Commission required delineation of sand and gravel reserves in the ACT so that exploitation of deposits could be considered in discussions on land-use. An augering program of 85 holes and 800 m of core sampling was completed in 1976, and size analysis carried out on sand and gravel samples.

Transport planning

A geological study of a number of alternative airport sites for Canberra was carried out for the National Capital Development Commission for their consideration in future planning.

Geological appraisals were made of possible routes for the proposed Canberra rapid transit system, and for several bridge sites for roads in Tuggeranong, including a major bridge across the Murrumbidgee River.

ENGINEERING GEOLOGY FOR FOREIGN AID PROJECTS

by

D.C. Purcell

Suva sewerage tunnel, Fiji

A report describing the results of site investigations, and design and cost estimates for a sewerage tunnel in Suva was prepared for the Fijian Government by the Department of Construction and BMR, acting for the Australian Development Assistance Agency.

The two alternative routes were considered geologically feasible. The tunnels will be driven under Suva City through sandstone, limestone and marl. Rock conditions in the marl are such that the tunnel may be almost completely unsupported and unlined, except for the portals and random rock bolting; the limestone will require steel set support along 80% of its section during excavation, and a full concrete lining will be necessary in the limestone and the underlying Veisari sandstone. The limestone is cavernous, with water flowing through solution channels.

Although the earthquake risk in Suva is high, the tunnel is unlikely to be affected except possibly along the limestone cliffs above the inlet portal.

Suva water supply dam

A week was spent traversing a 6-mile section of the Waimanu River and its tributary creeks in a search for suitable damsites. Two alternative sites were reported on, a lower site and an upper site. The upper site is geologically less complex than the lower site. The lower site is affected by landslides in the highly weathered and faulted andesite and siltstone. The upper site is well-jointed in moderately weathered andesite and there is no evidence for past or present landslide activity.

MAP EDITING AND COMPILATION

by

G.W. D'Addario

STAFF: G.W. D'Addario, W.D. Palfreyman, D.E. Gardner, M.J. Jackson (1-15 September), J. Mitchell (from 14 October), J.M. Bultitude.

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

A final draft of the Standard Geological Symbols booklet was prepared and a bibliography of maps was included. The booklet will be considered at the next Chief Geologists' Conference Adelaide.

EDITING

Fourteen 1:250 000, one 1:100 000 and seven special maps (ie. other than standard scale series maps) including the 1:2.5M scale map of Australia in four sheets, were edited. The editing of five special, one 1:100 000 and five 1:250 000 scale maps is in progress.

COMPILATION

GEOLOGY OF AUSTRALIA 1:2.5M SCALE

This 4-Sheet map was issued in August. The proposed fifth sheet, consisting of four 1:10M maps, will not now be published but the maps, which have been compiled, will be part of the explanatory notes. Some progress was made in writing the notes.

GEOLOGY OF NORTHERN TERRITORY 1:2.5M SCALE

The map was issued in August and the accompanying notes are being written.

BMR EARTH SCIENCE ATLAS

The detailed format and content of the proposed Atlas is currently under review but it is expected that most maps to be included in it will be at 1:10 000 000 scale, and that the Atlas will be in loose-leaf form with hard covers. The series will provide a valuable first reference to, and over-view of, the geology and geophysics of Australia for schools, geologists, overseas visitors and to private and governmental organizations (including Australian overseas diplomatic and trade offices). The following map sheets for the Atlas are in progress:

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

This 1:10 000 000 scale map which was produced for distribution at the 25th International Geological Congress, will form, with minor alterations and additions, the first sheet of the Atlas and will also be included in the 3rd Series of the Atlas of Australian Resources by Division of National Mapping.

The map shows sedimentary and metamorphic sequences by age colour and igneous rocks, by rock type, by overprinted stipples. Cainozoic cover is shown as far as is practicable at the scale of the map where bedrock geology is shown.

The map has been compiled and some work has been done on the accompanying notes.

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

Compilation is completed, editing is in progress. Notes have still to be written. The map will show sedimentary and metamorphic sequences by age colour and igneous rocks, by rock-type, by overprinted stipples. Laterite and superficial and unconsolidated sedimentary Cainozoic rocks are omitted giving, as far as possible, a portrayal of the bedrock geology of Australia.

Cainozoic thickness and weathering - Australia (G.W. D'Addario, W.D. Palfreyman, J.M. Bultitude).

Compilation of this map is completed and editing is in progress.

This map shows the main Cainozoic depositional areas and basalt with thickness in metres, main areas of ferruginous or aluminous duricrust, exposed mottled, pallid zone material or partially kaolinised country rock. Selected recorded depths of weathering, in metres, are shown by numerals.

Surface drainage and continental margins - Australia (G.W. D'Addario, W.D. Palfreyman, with contributions by Marine and Gravity Sections, Geophysical Branch).

Compilation of this map is completed and editing is in progress.

This map shows areas of direct and indirect external and internal drainage, areas of deranged drainage and areas without surface drainage. The continental margin and ocean floor have been subdivided to indicate the major seafloor features.

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

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

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

The compilation is completed. This map was compiled from the 1971 Tectonic map of Australia and New Guinea at 1:5M

scale, and adopts the same subdivision as that map: orogenic provinces, transitional domains and platform cover.

Main Rock Types - Australia (G.W. D'Addario, W.D. Palfreyman, J.M. Bultitude)

Compilation is completed and editing is in progress. This map shows igneous and consolidated and unconsolidated sedimentary rocks with metamorphosed sedimentary and volcanic rocks subdivided into low-grade and medium and high-grade metamorphic rocks. Sand and laterite, which cover about 90% of the igneous and metamorphic rocks in southern Western Australia, are not shown.

INDEXES, TECHNICAL AND MINERAL REPORTS

by

K. Modrak and N.D. Knight

STAFF: K. Modrak, N.D. Knight, L. Kay, M. Tacon (also assists Map Editing Group), M. Pollington (resigned 16 January), C. Kidd (12 July to end August), P. Vanden Broek (part-time from 5 October).

STRATIGRAPHIC INDEX

Literature on Australian geology received through the Bureau Library was indexed under the headings - stratigraphic name, author, 1:250 000 Sheet area, Basin name and subject headings (the ANGI thesaurus was replaced by AMF thesaurus on 18 May). Copies of the index cards were sent to the Bureau Library, BMR Basin Study Group and State Geological Surveys. New stratigraphic names indexed were added to the Central Register of Stratigraphic Names and all references to these and previously published names were noted in the card index. Bi-monthly variation lists and the yearly deletions list noting additions to and deletions from the Central Register, were compiled and sent to State Subcommittees of the Geological Survey of Australia's Stratigraphic Nomenclature Committee, State Geological Surveys, Universities and interested companies.

An information sheet on the role of the Central Registry of Stratigraphic Names was compiled and is available to all interested people. An article on the index, as maintained by the Registry written in conjunction with E.K. Carter, was published in the BMR Journal. Compilation by G. Nolan of the

Antarctic Lexicon commenced in February. Some standardisation problems have been encountered and I. McLeod is sorting out this aspect.

TECHNICAL FILES

Indexing of unpublished data and newspaper clippings continued; these were filed under 1:250 000 Sheet areas.

MINERAL INDEX AND MINERAL REPORTS

The bibliographic index to current literature on mineral deposits (arranged by Commodity and State) and a card index of major mineral deposits were maintained throughout the year.

Work was done, in conjunction with the Mineral Resources Branch, compiling data on the antimony, copper and tungsten deposits of Australia.

MUSEUM AND TRANSIT ROOM

by

D.H. McColl

MUSEUM

STAFF: D.H. McColl (mineralogist-petrologist), J.E. Mitchell (geologist), G.D. Nolan (Transit Room Officer), J.D. Reid, (Technical assistant/cataloguer).

COLLECTIONS

The outstanding contribution made to the reference mineral collections this year was the magnificant donation by Mr Clement V. Latz of Adelaide. It comprises over 2000 specimens, most of which are large colourful finely crystallized pieces well suited to museum display applications. A good proportion are historic Australian materials particularly from the long-abandoned South Australian copper districts of Burra and Moonta-Wallaroo Mines and from Broken Hill. From overseas, oxidised copper-lead minerals from the famous deposits at Tsumeb in South West Africa and antimony-lead-zinc sulphides from Trepea in Roumania are

prominent in the collection. These are rarely seen in this country in such fine quality. The collection is by far the most valuable in our care. The donation has been made to the Commonwealth Government for the recommended National Museum, with BMR to act as custodian.

Specimens were also acquired by field collecting, exchange and minor purchases, particularly some fine pieces from classical Japanese and European sites obtained through delegates at the International Geological Congress held in August. An outstanding donation was of four fine crystal groups from the German Democratic Republic.

Revision and recataloguing of two older collections gave the following statistics,

C.B. Askew Mineral Collection - 1021 specimens;

A.R. Campbell Mineral Collection - 945 specimens.

Both collections were valued and have appreciated considerably.

Similar work, which will now be further delayed by receipt by the Latz specimens, is still proceeding on the R.W. Doo Mineral Collection.

Efforts are being made to organise the Australian rocks and ores into accessible reference collections as has been done with the minerals. A greatly appreciated donation of fine polished ornamental stones was received from Monier Granite Limited in Adelaide for this purpose.

RESEARCH AND EXTERNAL SERVICES

Mineralogical investigations and determinations were carried out within the limitations of available staff. Minor petrological, petrographic or gemmological problems were also tackled when required; most of these come from the general public and other government departments. They range from the most casual telephone enquiries through to complex mineral chemistry investigations requiring hours of work in liaison with other sections. This activity shows that Canberra lacks a state museum, mines department, or equivalent source of general earth science information.

Other institutions that assisted in various ways during the year include the Australian National University, Canberra Technical College, the Canberra Gem Society, the Canadian High Commission, Monash University, the Australian Museum and the

University of Adelaide. Advisory and other services have been rendered to other divisions of the Department of National Resources and to the National Museums Secretariat of the Department of Administrative Services.

Internal mineralogical/petrological projects still pending involve the following topics -

(i) The secondary copper lead mineralization of Brown's Deposit, Rum Jungle, NT.

(ii) Pseudomalachite mineralization at West Bogan Mine, Nyngan, NSW.

(iii) Crystallized sulphides and sulphosalts of the Tolwong Mine, Marulan, NSW.

(iv) The 53 stony meteorites of the Popio Lake district, Western NSW.

(v) The "Thackaringa" and "Nilpena" new stony meteorite finds.

EXHIBITIONS

The main activity this year was participation in the BMR contribution to the 25th International Geological Congress. Part of the exhibit was prepared by the museum, a paper was provided for the museums symposia, and help given with the special excursions of the International Mineralogical Association. Liaisons made with foreign museums and research institutions during the Congress should be invaluable to further the progress and national and international status of the BMR museum.

At the end of August a single small showcase of spectacular pieces from the newly received Latz collection was provided for the four-day Second National Exhibition of Minerals at Glen Waverley in Victoria. This function has developed into a major annual convention of museum personnel and mineral dealers and is providing a valuable national forum by which awareness of mineral discoveries and price fluctuations is maintained. In October three showcases of specimens were provided as our annual contribution to the Canberra Gem Society Exhibition. Displays also continued to be maintained in the corridors and foyer of the BMR Building and in the departmental regional office in Sydney.

EDUCATIONAL SERVICES

Many organised visits by classes of school children were catered for by the museum. Sets of minerals suited to teaching were provided on formal request; they are much in

demand. These are commonly used in practical exercises by teachers and must be considered expendable; the demand for this service is therefore a continuing one and will possibly increase. It derives mainly from Canberra secondary schools, including Canberra Technical College, and the School Without Walls; troops of the local Scouting movement have also sought assistance.

VISITORS

Present staff and facilities limit the extent that we are able to act as an earth science museum for tourists and the general public of the Canberra region, but every effort was made to provide this public service. Many different enquiries are received over a wide range from all kinds of people. The visitors' book records 568 visitors but does not include a number of school classes or casual visits from BMR personnel. Most visitors come to make enquiries about amateur prospecting or gemmology but the increasingly valuable and spectacular collections in our care are also attracting attention.

TRANSIT ROOM

Samples collected by survey parties requiring petrological, petrographic, chemical or radio-isotope investigations are forwarded through contractors or relevant Bureau Laboratories by the transit room officer, who also keeps the recovery journal and other records. It is still intended, as staffing permits, to unify past and present research and project data into a single easily-operated retrieval indexing system which would ideally be computerised.

The total number of samples processed decreased because of economic restraints from 10 041 last year, to 6637 this year.

GEOLOGICAL DRAWING OFFICE

by

P.A. Boekenstein and H.F. Hennig

STAFF AND GENERAL

At 31st October 1976, the Drawing Office staff consisted of 33 Draftsmen, 9 Drafting Assistants and 3 Photographers. P.A. Boekenstein is Chief Draftsman. H.F. Hennig was promoted to Assistant Chief Draftsman on 20th May.

Investigations continued into the application of computer techniques to the production of geological and geochemical maps.

Three members of the cartographic staff worked in the field with geological field parties: P. Blythe, Duchess Party; J. Mifsud, Lawn Hill Party; P.P. Jorritsma, Georgetown Geochemical Party.

PRODUCTION

(November 1975 to October 1976 inclusive)

Supervising Draftsmen: E. Feeken, K. Matveev, R. Molloy, I. Chertok.

MAPS FOR PUBLICATION	1:100 000	1:250 000	Other Scales
Preliminary Edition			
Compilation by BMR in progress at 31.10.76	9	7	5
Compilation by BMR completed (ready for printing)	1	3	2
Maps printed	9	5	3
1st or 2nd Edition			
Fair drawing in progress at 31.10.76			
BMR	-	-	13
Contract*	-	17	-
Fair drawing completed:			
BMR	-	-	5
Contract*	2	15	5
**Printing in progress at 31.10.76			
BMR	2	22	4
GSWA	-	3	-
Printing completed			
BMR	-	11	24
GSWA	-	2	-
Reprinting completed:	-	-	2

Notes:

*Contract drafting stages over the period: specifications prepared - 22 maps; contractor recommended - 14 maps; first proof checked - 20 maps; second proof checked - 19 maps.

**Printing stages over the period: specifications parepared - 29 maps; colour designs and colour guides prepared - 31 maps; performance supervised as required, screenmasters and dyeproofs checked - 41 maps; machine proofs checked - 36 maps; printed maps checked - 36 maps.

GSWA maps: Geological Drawing Office prepares contract specifications, supervises performance as required.

Reprinting: Geological Drawing Office checks repromat, prepares specifications, supervises performance and checks proofs as required.

SPECIAL MAPS (included in statistics above):

Fair drawing and printing of the 4 sheets of the 1:250 000 geological map of Australia were completed. Fair drawing of 1:500 000 geological maps of Kimberley Basins North and West, Victoria River Region and Cobourg Peninsula-Melville Island was completed and printing is in progress, and printing of the 1:2 500 000 geological maps of Papua New Guinea and Northern Territory and the Cainozoic stratigraphy of Northern Territory was completed. Fairdrawing and printing of 1:10 000 000 geological map of Australia and the postcard geological map of Australia, were completed in time for the 25th International Geological Congress.

FIELD COMPILATIONS: (1:250 000 and 1:100 000 Sheet areas):

21 completed: 11 in progress.

TEXT FIGURES, DIAGRAMS, PLATES:	Completed	In progress
Records and miscellaneous (including figures for I.G.C.)	974	91
Reports	44	11
Explanatory Notes	60	6
Bulletins	141	126
Outside publications	15	-
Transparent slides for I.G.C.	156	-

PICTORIAL INDEX OF ACTIVITIES:

The index to 31.12.75 was compiled and published. Preparation has commenced of a broadsheet brochure showing progress of geological mapping in Australia.

COSTS OF PRODUCING 1:250 000 COLOUR MAPS

The average costs of producing 1st edition 1:¼M geological maps in 1976 (with comparative figures for 1975) were:

Contract drafting, based on 14 maps, $1200 per map (14 maps at $1140 per map in 1975).

Contract printing, based on 16 maps, $4000 per map - $405 per colour (12 maps at $4320 - $440 per colour in 1975).

APPENDIX

APPENDIX

PUBLICATIONS AND RECORDS*

*Numbers against authors' names indicate that the author: [1]was formerly a BMR officer; [2]is, or was, an officer of an Australian State Geological Survey; [3]is a CSIRO member of the staff of the Baas Becking Geobiological Research Laboratory; [4]is a non-BMR author with other affinities.

Preliminary and routine reports are issued in multilithed form as BMR Records. This is an unpublished series used where early release of information is thought desirable. Only a limited number of copies is prepared; wide distribution is not possible. Those available to the public for reference are listed in Open File Circulars, which also list the centres at which copies of each Record are held. Details of the system are given in the Open File Circulars.

BULLETINS

PUBLISHED OR IN PRESS

151. BURGER, D. & [1]NORVICK, M.S. - Stratigraphic palynology of the Cenomanian of Bathurst Island, Northern Territory, Australia. (pp. 1-20)

151. [1]NORVICK, M.S. - Mid-Cretaceous microplankton from Bathurst Island. (pp. 21-113)

151. BURGER, D. - Cenomanian spores and pollen grains from Bathurst Island. (pp. 114-169)

153. SHERGOLD, J.H. - Late Cambrian and Early Ordovician trilobites from the Burke River Structural Belt, western Queensland, Australia. (2 Vols, 251 pp., 58 pls.)

156B. DICKINS, J.M. - Correlation chart for the Permian of Australia.

158. DRUCE, E.C. - Conodont biostratigraphy of the Upper Devonian reef complexes of the Canning Basin, Western Australia.

159. OPIK, A.A. - Cymbric Vale fauna and Early Cambrian biostratigraphy.

160. KEMP, E.M. - Palynological observations in the Officer Basin, Western Australia. (pp. 23-43)

160. BURGER, D. - Some Early Cretaceous plant microfossils from Queensland. (pp. 1-22)

162. PAGE, R.W. - Geochronology of igneous and metamorphic rocks in the New Guinea highlands.

163. MARSHALL, J.F. - Marine geology of the Capricorn Channel area.

165. SMITH, I.E., DAVIES, H.L., & BELFORD, D.J. - Geology of southeastern Papua.

166. EXON, N.F. - The geology of the Surat Basin in Queensland.

168. SWEET, I.P. - Precambrian geology of the Victoria River region, Northern Territory.

171. POJETA, John Jnr, GILBERT-TOMLINSON, Joyce, & SHERGOLD, J.H. - Cambrian and Ordovician rostroconch molluscs from northern Australia.

174. POJETA, John Jnr, & GILBERT-TOMLINSON, Joyce - Australian Ordovician pelecypod molluscs.

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