REPORT 194

Geological Branch
Summary of Activities
1975

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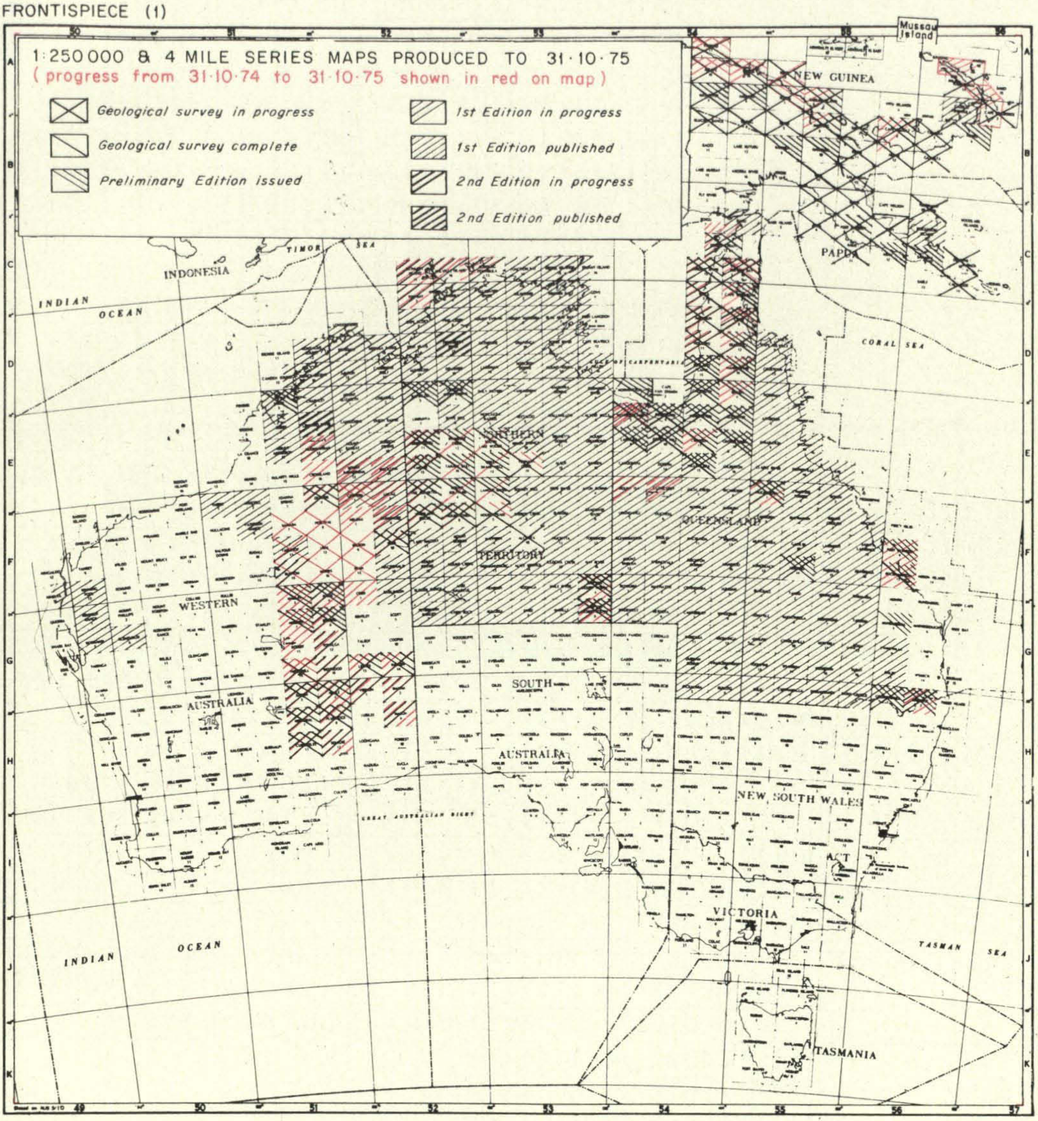

ANTARCTICA - 1:250 000 SERIES MAPS PRODUCED TO 31·10·1975
(sheets issued 1975 in red)

FIELD WORK IN PROGRESS

GROVE MOUNTAIN	SS 40 - 42/15	SULLIN MONOLITH
MOUNT MENZIES	WILSON BLUFF	
MOUNT TWIGG	CHURCH MOUNTAIN	

PRELIMINARY EDITION ISSUED

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

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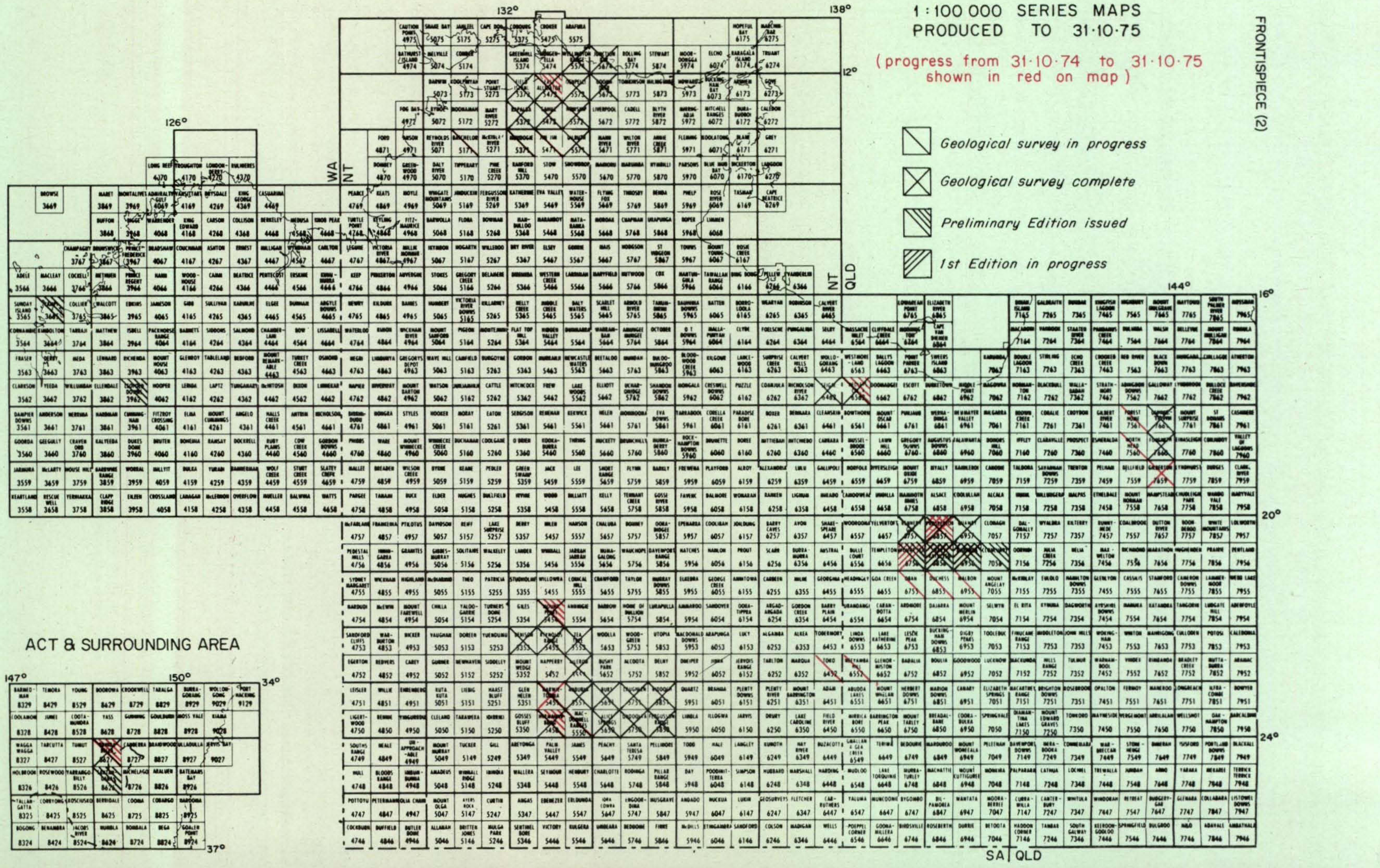

Record 197

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

REPORT 194

Geological Branch Summary of Activities 1975

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA, 1976

DEPARTMENT OF NATIONAL RESOURCES
MINISTER: THE RT HON. J. D. ANTHONY, M.P.
SECRETARY: J. SCULLY

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

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GEOLOGICAL BRANCH

SUMMARY OF ACTIVITIES

1975

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SEDIMENTARY SECTION
by G. E. Wilford

Reconnaissance geological mapping of sedimentary basin areas continued. Eight 1:250 000 Sheet areas were mapped in the Canning Basin in co-operation with the Geological Survey of Western Australia, and a further six sheet areas were re-mapped in the Wiso Basin, Northern Territory (Fig. S1); helicopters were used in both mapping programs. Shallow stratigraphic drilling was undertaken in the Wiso Basin. A meteorite crater was discovered in the southern part of the Canning Basin. Reporting on earlier surveys in the Carpentaria, Eromanga, Ngalia, and Officer Basins continued. The outstanding geological maps and explanatory notes for Cape York Peninsula were completed, and a start was made on preparing a synthesis of the geology of the Carpentaria Basin to be published as a Bulletin with accompanying 1:1 000 000-scale geological maps. Bulletin 167C, on the geology of the northwestern part of the Eromanga Basin, was written; this completes the reporting on the Queensland and Northern Territory parts of the basin; Bulletins 167A and B on the northern and central parts were completed in 1974. Each Bulletin, prepared in co-operation with the Geophysical Branch, is accompanied by 1:1 000 000-scale geological, isopach and structure contour maps.

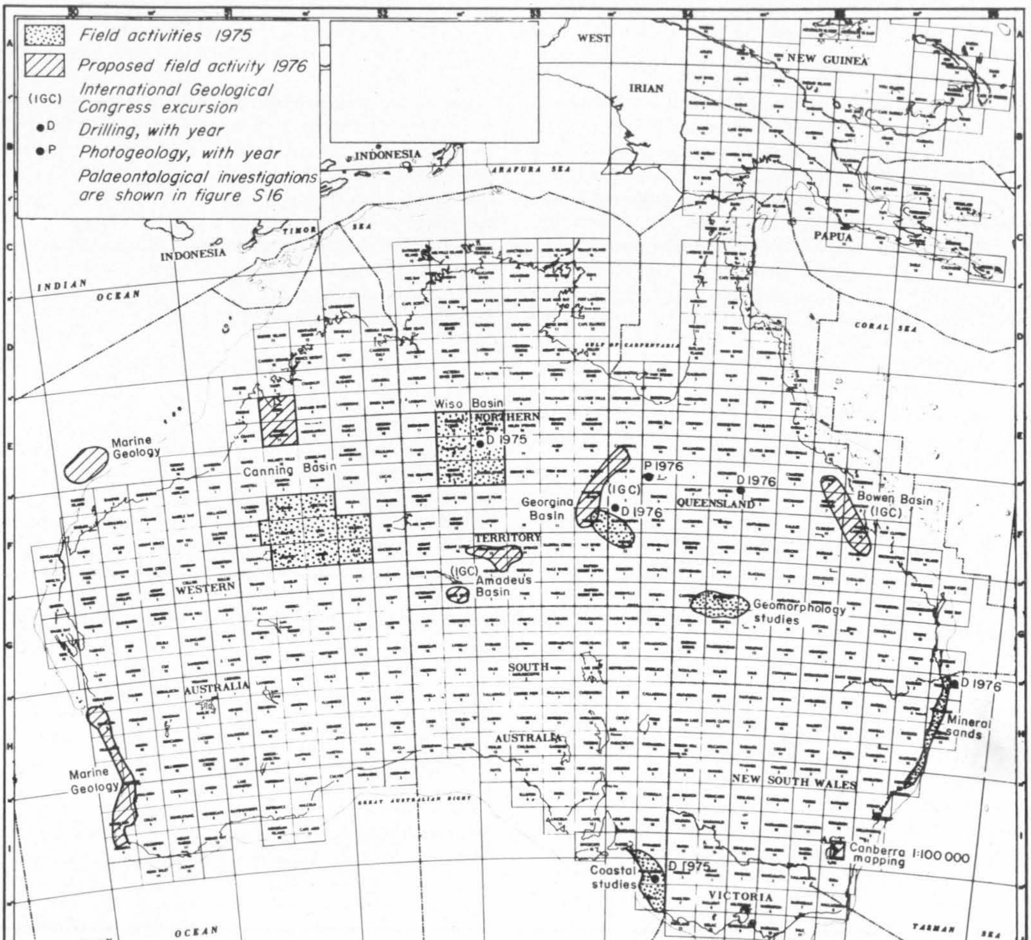

Figure S1 Sedimentary Section field activities, 1975-76.

Studies of deep weathering, landform development, and neotectonics in southwest Queensland continued in 1975. A map of the weathering profiles and geology at 1:250 000 scale was prepared, and lineaments visible on airphotographs and Landsat-1 (ERTS-1) imagery were analysed. Palaeomagnetic studies on iron-rich profiles in co-operation with the Geophysical Branch show promise of dating some weathering events. Field activities in the Georgina Basin were continued along the southern margin where the lithological variations and interrelationships of mainly Adelaidean to Ordovician units were studied. Analysis of data collected from the *TANTANGARA* and *BRINDABELLA* 1:100 000 Sheet areas (western part of the *CANBERRA* 1:250 000 Sheet) continued, and a preliminary edition of the *BRINDABELLA* Geological Sheet was issued. A suite of chemically distinctive Siluro-Devonian granitic and volcanic rocks in this part of the Lachlan Fold Belt forms a belt spatially related to the earlier Ordovician Molong Volcanic Arc.

Work on calibration of the mathematical model of the Great Artesian Basin continued throughout the year. A new model was designed (GABHYD) which was more compatible with the CYBER 76 computer, and which processes 15 times faster than the previous GABSIM model. Steady-state calibration was achieved, and a start made with documenting the results of the project. Assistance was given to the Australian Atomic Energy Commission (AAEC) in its study of isotopes in the groundwaters of the Great Artesian Basin. Early results from investigations along the northeastern margin of the basin show water flow rates of the order of 5 m per year, and some inter-aquifer flows compatible with the known geological conditions. Water-bore logging continued, 96 logs being obtained in the N.S.W. parts of the Eromanga and Surat Basins. At the end of the year logging was being undertaken in the bores sampled by the AAEC.

The Photogeology and Remote Sensing Group gave assistance to field parties, and ran training courses. Evaluation and interpretation of satellite (Landsat and Skylab) imagery continued, and considerable time was spent on administrative matters connected with the Australian Committee for Earth Resources Technology Satellites (ACERTS).

Shallow seismic profiling was undertaken over the N.S.W. continental shelf from Newcastle to the Queensland border to determine the thickness and structures of the superficial sediments. The interpretation of sedimentological, geochemical, seismic, and bathymetric data for the east Australian and east Tasmanian shelf continued. Information on deep sea drilling in the Indian Ocean was compiled, and the pattern of Mesozoic-Cainozoic sedimentation determined in relation to continental dispersal. Palynological work on Deep Sea Drilling Project cores shows that vegetation in the Ross Sea area of Antarctica persisted until the Late Oligocene, and that the summit of the Ninetyeast Ridge in the Indian Ocean was once emergent as a string of islands closer to the Australian continent than now.

A series of raised sand ridges in southeast South Australia was investigated by shallow stratigraphic drilling. The project, in co-operation with the S.A. Department of Mines and Flinders University, has the primary aims of establishing a Quaternary sea level curve, and determining the likely heavy mineral potential.

Uranium-series dating techniques were used to date corals from Papua New Guinea, the Great Barrier Reef, the east coast of Australia, and the Loyalty Islands.

The bibliographic study of Quaternary coastal deposits containing heavy-mineral sands, and preparation of maps showing their distribution and factors fundamental to their accumulation, have been completed for the east coast of Australia, and extended to the south coast (excluding Western Australia). The study indicates that some of the largest accumulations are along high-wave-energy coasts which have small tidal ranges and narrow shelves, and which have evidence of a long and complex Quaternary history of erosion and deposition. The documentation of earlier studies of evaporites continued.

The computing group continued to write programs for the Branch library which now contains 50 programs and sub-routines stored on magnetic tape. Work continued on a system of indexing geological data by project.

Several members of the Section were involved in preparatory work for IGC excursions to be conducted in August, 1976.

The Palaeontological Group continued the systematic description of faunas and floras from Australia, New Guinea, and Antarctica, and worked closely with field geologists mapping in the Canning, Georgina, Carpentaria, and Wiso Basins. Studies included Precambrian microfossils and stromatolites, Lower Palaeozoic trilobites, Upper Palaeozoic conodonts, fishes, molluscs and ostracods, Mesozoic molluscs, Cretaceous floras and Cainozoic floras, mammals, and foraminifera. Studies of calcareous nannofossils were started.

METALLIFEROUS SECTION
by W. B. Dallwitz

Figure M1 shows the areas where geological mapping and related activities of various kinds were undertaken by, in co-operation with, or for the Section in 1975, and where similar work is planned for 1976.

Report writing, map compilation, and/or laboratory work continued for about forty projects or parts of projects for which mapping and field collecting had previously been completed or largely completed.

Almost all the geological mapping carried out by the Section during the year (1/11/74 to 31/10/75) was of a semi-detailed nature, and was done at 1:25 000 scale, or greater, mostly using colour aerial photography; it has as its aim the production of maps at 1:100 000 scale. In Australia only the *LANDER RIVER* and *MOUNT SOLITAIRE* Sheet areas were mapped, in co-operation with the Sedimentary Section, for production of 1:250 000-scale maps; some reconnaissance mapping was also carried out in Antarctica.

Semi-detailed mapping, coupled with ground geophysical surveys, isotopic dating, geochemical sampling, and drilling in some areas was carried out in the Arunta Block, the Pine Creek Geosyncline, the Cloncurry and Duchess areas, and the Georgetown Inlier. Volcanic units in the Pilbara area were sampled as part of the IGCP Archaean Geochemistry Project.

Since semi-detailed mapping of the Arunta Block began in 1970, three major stratigraphic divisions of the metamorphic rocks have been recognized, at least two Precambrian orogenic cycles (about 1800 and 1700 m.y. ago) involving partial melting and the formation of granite batholiths and granulitic residues have been

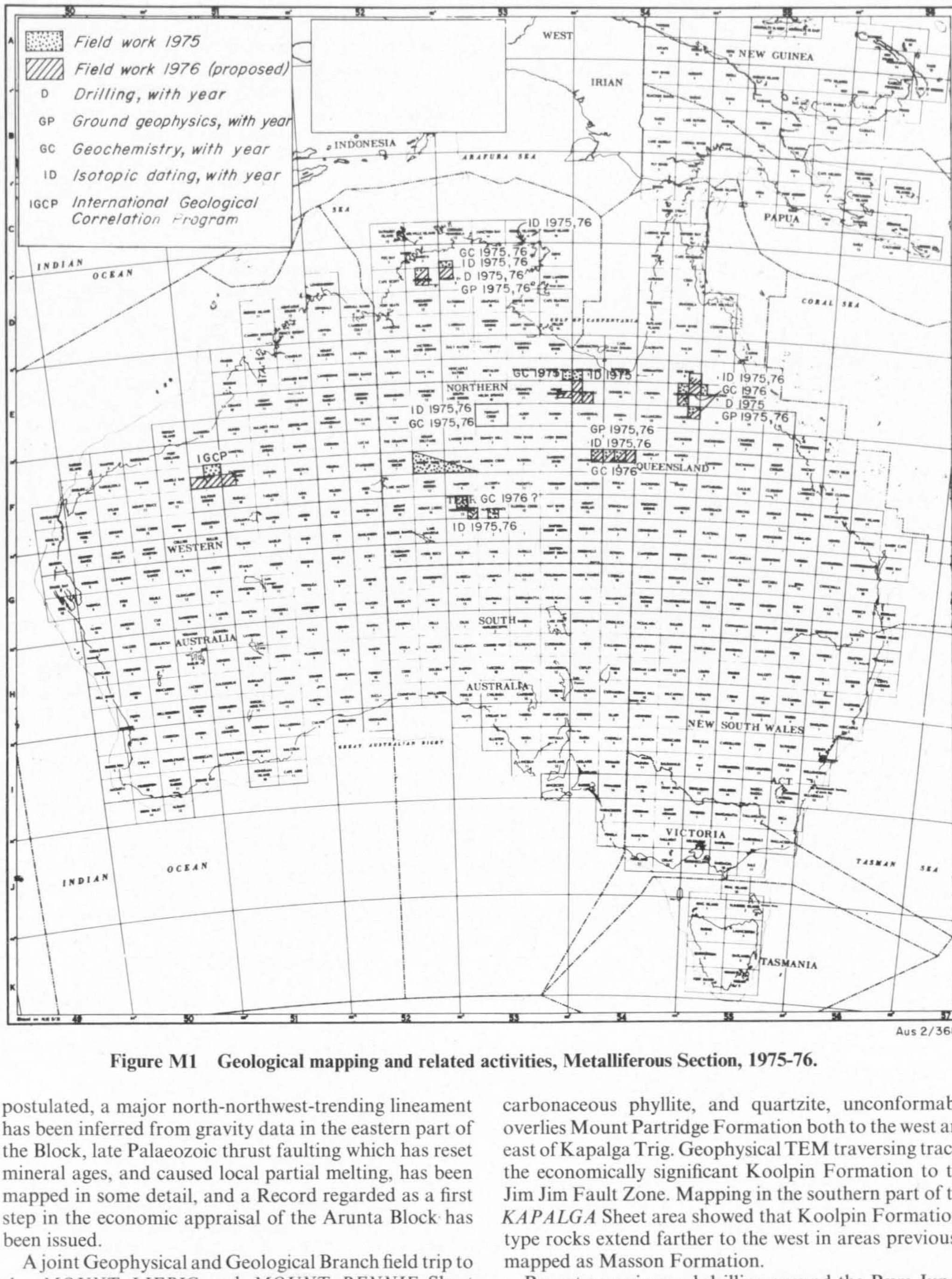

Figure M1 Geological mapping and related activities, Metalliferous Section, 1975-76.

postulated, a major north-northwest-trending lineament has been inferred from gravity data in the eastern part of the Block, late Palaeozoic thrust faulting which has reset mineral ages, and caused local partial melting, has been mapped in some detail, and a Record regarded as a first step in the economic appraisal of the Arunta Block has been issued.

A joint Geophysical and Geological Branch field trip to the *MOUNT LIEBIG* and *MOUNT RENNIE* Sheet areas had as its aim the collection of specimens whose physical and petrographic properties are being examined with a view to finding the explanation for magnetic anomalies over areas previously mapped and/or photo-interpreted as granite.

Drilling in the central eastern part of the *KAPALGA* 1:100 000 Sheet area showed that the Koolpin Formation, consisting of phyllite with bands of dolomite, carbonaceous phyllite, and quartzite, unconformably overlies Mount Partridge Formation both to the west and east of Kapalga Trig. Geophysical TEM traversing traced the economically significant Koolpin Formation to the Jim Jim Fault Zone. Mapping in the southern part of the *KAPALGA* Sheet area showed that Koolpin Formation-type rocks extend farther to the west in areas previously mapped as Masson Formation.

Recent mapping and drilling around the Rum Jungle and Waterhouse Complexes and the Burnside Granite have helped to clarify the relation between these rock bodies and the sediments of the Pine Creek Geosyncline, but further work is required to understand the relations of sedimentary units in the area between the two complexes and the Burnside Granite.

Geological work in Enderby Land, Antarctica, was hampered by poor weather and the loss of two aircraft.

Probably the most interesting discovery was a quartz-magnetite rock containing up to 40 per cent Fe. Samples of an unusual potash-rich dyke rock and lava collected by earlier expeditions at Mount Bayliss, Prince Charles Mountains, were both found to contain the rare potash amphibole, magnophorite; similar rocks have been found only in the Leucite Hills, Wyoming, the West Kimberley area, W.A., southeastern Spain, and Montana.

Critical areas in the *MOUNT ISA*, *MARY KATHLEEN*, *MARRABA*, and *QUAMBY* 1:100 000 Sheet areas were re-examined in collaboration with geologists of the Geological Survey of Queensland, and a geologist worked with a ground geophysical party tracing Precambrian basement beneath thin Mesozoic cover in the *CLONCURRY* 1:100 000 Sheet area, where magnetic and gravity anomalies have been attributed to jaspilite and banded iron formation in the contact aureole of granite.

Semi-detailed mapping of the *OBAN*, *DUCHESS*, and *MALBON* 1:100 000 Sheet areas was started by a joint BMR-GSQ party. Evidence was found of a major unconformity between crystalline basement consisting of granite (previously mapped as Kalkadoon Granite) and relatively high-grade metamorphics, and an overlying sequence of volcanic and sedimentary rocks which includes the Mount Guide Quartzite and units tentatively correlated with the Magna Lynn Metabasalt and the Argylla Formation. The Kalkadoon Granite, as previously mapped, also includes younger granitic masses which, in the Duchess area, intrude acid and basic volcanics correlated with the Leichhardt Metamorphics and Magna Lynn Metabasalt, respectively.

Mapping of the *SEIGAL* and *HEDLEYS CREEK* 1:100 000 Sheet areas was carried out in 1972-73. The name Nicholson Granite Complex has been proposed for the bodies formerly known as the Nicholson and Norris Granites. They represent a series of comagmatic intrusions, spanning about 70 to 90 m.y., interrupted by the extrusion of the chemically related Cliffdale Volcanics, which are themselves intruded by the younger parts of the Complex. The Volcanics, dated at about 1770 m.y., define the base of the Carpentarian in Australia.

The first phase of the Georgetown Project was completed with the mapping of the *GILBERTON* 1:100 000 Sheet area by a joint BMR-GSQ party during 1975. Report writing and map compilation are in progress, and will incorporate the results of geochemical and geophysical surveys, isotopic dating, and various laboratory studies. Field evidence suggests that the Etheridge Formation, Robertson River Metamorphics, Bernecker Creek Formation, and Einasleigh Metamorphics are stratigraphically equivalent, and that differences between them are due to differences in metamorphic grade and original rock type. An area of hydrothermally altered Forsayth Granite, discovered this year about 12 km west of Georgetown, offers promise as a porphyry copper prospect.

A laboratory study of a zone of blueschists, eclogites, and associated rocks from the south Sepik area of Papua New Guinea showed that these rocks form part of the southern high-pressure belt of a paired metamorphic complex, and are derived mainly from gabbro and basalt of possible oceanic island affinities. The mineralogy and mineral chemistry of the rocks point to metamorphism at depths of 25 to 50 km. The metamorphic temperatures (350-650°C) and pressures were probably generated in a northward-dipping subduction zone, active in the Oligocene, between the Australian Plate and a volcanic arc to the north. The leading edge of the upper plate can be recognized in places by the presence of northward-dipping remnants of an ophiolite complex.

Further work on the petrology of rocks from the volcanoes along the southern margin of the Bismarck Sea is helping to clarify the complex tectonics of the region, and the relation of active volcanoes to plate boundaries. A suite of volcanic rocks from islands northeast of New Ireland was found to range in composition from basanite to silica-saturated trachyte. Most of the strongly undersaturated rocks contain phenocrysts of zoned haüyne and of analcite. The tectonic conditions under which these unusual magmas developed remain to be elucidated.

Work on potassic basalts and island-arc-type andesites from the Highlands volcanoes of Papua New Guinea has confirmed that the volcanism is unrelated to any present-day or recent subduction, but may be related to an older episode of subduction which has chemically modified the mantle.

The BMR and the Elsevier Scientific Publishing Co. are jointly producing a volume of research papers entitled "Volcanism in Australasia" in honour of the late G. A. M. Taylor.

Several members of the Section were involved in planning excursions and writing guidebooks for the International Geological Congress.

All major analytical instruments in the Petrological, Geochemical, and Geochronological Laboratory have outputs for data processing, and most are on-line to computers.

Several members of the Laboratory staff took part in the Section's 1:100 000 mapping program.

A study of the petrology, geochemistry, and genesis of mafic granulites and acid to intermediate gneisses in the central part of the Arunta Complex is in progress.

Specimens were collected in the Pilbara region, Western Australia, as part of the IGCP Archaean Geochemistry Project. Archaean crustal studies involving comparisons between Australia and other continents are continuing in collaboration with university and other workers.

Geochemical and other geological evidence from basic intrusive rocks in the Mount Isa/Cloncurry area is tentatively interpreted as suggesting the former presence of a subduction zone in the east.

Following extensive monitoring, over some years, of water in the Molonglo River and Lake Burley Griffin, remedial treatment of tailings dumps at Captains Flat is to be carried out by the New South Wales and Australian Governments.

Systematic regional stream sediment geochemical surveys in the Westmoreland and Georgetown areas are beginning to prove their usefulness in pointing up areas worthy of further investigation. Both fine fractions and heavy-mineral concentrates are analysed after microscopic and, if necessary, X-ray examination of concentrates.

Analysis of soils from the Forsayth area showed that gold values exceeding 0.1 ppm in minus-180-micron fractions are reliable indicators of gold mineralization; however, equally reliable and more easily determined indicators in that area are bismuth, copper, lead, and silver.

Isotopic dating of the Mordor Complex, near Alice Springs, shows that it was emplaced about 1200 m.y. ago. Most of the granulite-facies metamorphism in the Arunta Block took place about 1800 m.y. ago, and was followed by a regional amphibolite-grade event about 100 m.y. later. Dating of the basement rocks suggests that sedimentation in the Amadeus Basin began not more than about 1080 m.y. ago. The late Palaeozoic Alice Springs Orogeny has largely to completely masked earlier events in places, thereby causing difficulties in elucidating the geological history of parts of the Arunta Block.

Samples of glauconitic rocks from Elcho Island were collected in situ for the purpose of attempting to resolve a conflict which has arisen because an age of about 780 m.y. was obtained on pebbles containing Middle Cambrian trilobites.

Dating of rocks in the Mount Isa Block and, to a lesser extent, in the Alligator Rivers area has run into problems because of the limitations of the Rb-Sr and K-Ar methods, and it is hoped that U-Pb work on zircons will help to elucidate the geological history of these and other areas.

Geological, geochemical, and sulphur-isotope studies of the Golden Dyke Formation and associated mineralization have shown that there are two major types of ore deposit within it—a concordant copper-lead-zinc type,and a discordant lead-zinc type.

The ability of calcium and magnesium carbonates to concentrate lead and zinc from saline solutions, and to act as sources of metals during diagenesis, is being investigated, as is the role of organic matter, including humic acids, in inducing the formation of ooids, and in building up abnormally high concentrations of metals in pore waters of sediments.

In the Baas Becking Laboratory various lines of investigation relevant to the role of organisms, organic matter, and some inorganic substances in concentrating metals in the aqueous environment continued. High concentrations of phosphate and organic matter were found to increase the tolerance of sulphate reducers to heavy metals, and lowering of pH resulted in reduced tolerance. Certain algae and bacteria in shale, chert, and dolomite from the McArthur Group contain or are encrusted by sulphides, and therefore appear to have played some part in their formation.

Stable isotope studies strongly suggest that contamination of ancient kerogens by younger organic materials is negligible; however, there are indications that metamorphism may affect the isotopic composition of kerogens, and investigation of materials from various Archaean terrains is proceeding.

Sulphur isotope studies are being carried out on materials from a number of areas and on different types of mineralization, including nickel ores from Western Australia. In other work preliminary results suggest that ion exchange and diffusion during diagenesis are unlikely to have major effects on the fractionation of sulphur isotopes in sediments.

Geochemical and petrological investigations of diamond drill cores of rocks around base-metal sulphide deposits in the Lachlan Fold Belt are being carried out with a view to establishing metallogenetic models and exploration guides. Results from the Woodlawn area show that some basic rocks are less affected by hydrothermal alteration in the vicinity of the orebody than are felsic volcanics. In the latter, Si, Mg, Ag, Zn, Pb, and Sn were the main elements added, and Na and Ca the main elements removed. The ratio of K/Na shows a marked increase in the alteration halo around the orebody, and non-pyritic Fe/total-rock Mg increases away from the orebody.

During the course of an overseas visit a member of the Baas Becking staff spent some time on experimentally investigating the production of methane and hydrogen from waste material.

GEOLOGICAL SERVICES SECTION
by E. K. Carter

Substantially, the objectives and program of the Section were similar to those of recent years, and no large organizational changes took place. The forthcoming 25th International Geological Congress became a significant factor in the Section's workload, and the Section participated in the running of the Government Geologists' Conference and the related excursion held in May.

The Engineering Geology and Hydrology Subsection, as usual, collaborated with the Engineering Geophysics group. Most of the work performed by the Subsection related to Canberra and its environs, but assistance was also given, in collaboration with the Geological Survey of Victoria and consultants, to the Geelong Regional Development Authority. Further work was done on the Darwin East development study, Ramu 1 hydro-electric scheme and Purari River system hydro-electric development studies in Papua New Guinea; new projects included Newcastle Dry Dock and the Australian National Animal Health Laboratories near Geelong. In the Australian Capital Territory and environs, construction services continued on the Tuggeranong Sewer Tunnel and Molonglo Valley Interceptor Sewer, and began on Googong Dam, Queanbeyan River. Geological design investigations were carried out at the urgent request of the Department of Housing and Construction on the Ginninderra Sewer Tunnel. Work, generally feasibility studies of various types, was done on several other dams and sewer lines, and on water main routes and reticulation reservoir sites. In the field of district urban development, most work undertaken was a continuation or follow-up of last year's work, but advances were made in knowledge of the stratigraphy, structure, and soils of the area, and of the geotechnical implications of these factors. Work was carried out in all existing, or currently planned, urban districts. Four studies of materials resources—sand and gravel, rock, decomposed granite and brick shale—were made; several building sites and one bridge site were investigated. Four drainage problems, including remedial treatment, were investigated; hydrological studies, including Lake George and Jervis Bay, were maintained, and five bores were sited. Further progress was made in the preparation of maps for publication, including the 1:100 000-scale engineering geology series and a revision and extension of the 1:50 000 *CANBERRA* Special map.

The map editing and compilation group and the Geological Drawing Office had a larger output than last year. Thirty-eight maps were edited, and nine are in progress; drawing of 23 maps (other than text figures and plates) was completed, and 45 are in progress; 46 maps were printed, and printing of 17 is in progress. 1224 text figures and plates for publications and Records were drawn, and 376 are being drawn. A dye proof of the 1:2 500 000 geological map of the Northern Territory is with the printer, and the N. T. Cainozoic stratigraphy map and the 5-sheet 1:2 500 000 geological map of Australia are being fair drawn.

The Register of Stratigraphic Names and Catalogue of Definitions was maintained on behalf of the Geological Society of Australia. Bimonthly variations lists and an annual deletions list were issued. A study is being made of the feasibility of converting the register to machine-readable form.

Three Mineral Resources Reports were written (Molybdenum and Antimony) or revised (Tin), and the mineral deposits index was maintained.

Two major collections of display minerals were acquired by the Museum during the year—the Noble collection by purchase, and the Chidley collection by donation to the national collection. In addition, other notable mineral, australite, and meteorite specimens were obtained by field collecting, exchange, and purchase. The Curator of the Museum arranged displays for, and participated in, four major external exhibitions and maintained, with frequent changes, displays within the Bureau. A high level of interest in minerals, gems, and rocks continued to be displayed by the increasing number of visits to the Bureau museum by interested people, including groups of school children.

The Transit Room handled 10 041 samples for sectioning, chemical analysis, or age determination.

Considerable attention was given to staff development through the year by participation in staff lectures, Departmental training courses, Australian Mineral Foundation courses, a special course on rock mechanics given by Dr B. K. McMahon, study leave, attendance at conferences, and on-the-job training.

Three text publications prepared in the Section were submitted to the editors or sent to press, and two others have been written. Two special maps are in press, and five others have been compiled or are being fairdrawn; some have Explanatory Notes. Sixteen Records by the Section were issued, eight are in process of issue, and thirteen others were written.

SEDIMENTARY SECTION

Officer-in-charge: G. E. WILFORD

REGIONAL MAPPING PROJECTS

CARPENTARIA BASIN, BY H. F. DOUTCH

STAFF: H. F. Doutch, J. Smart, D. L. Gibson, B. S. Powell; K. G. Grimes (GSQ).

The main objectives of the Carpentaria Basin project are to understand the Mesozoic and Cainozoic geology of the onshore part of the area, and to publish results in the form of 1:250 000 geological maps and Explanatory Notes, a Bulletin synthesizing the geology of the whole area accompanied by 1:1 000 000 geological maps, an assessment of geophysical data by the Geophysical Branch, and papers on specific aspects of the geology. Geological mapping started in 1969 and finished in 1973; reporting should be completed in 1976.

During the year all the 1:250 000 geological maps and Explanatory Notes outstanding for complete coverage of Cape York Peninsula were put in the hands of the editors, leaving only the Basin area near the Northern Territory/Queensland border to be completed (presently covered by the Preliminary Maps and Records). Bulletin writing began. Doutch submitted a paper for publication proposing separation of a Cainozoic Karumba Basin from the underlying Carpentaria Basin, the two being tectonic entities of differing affinities; he also began a paper on Cainozoic tectonics and geomorphology of Cape York Peninsula. Grimes and Doutch completed a paper on the late Cainozoic deposits of the Carpentaria Plains. The implications of these three papers for the Cainozoic history of this part of eastern Australia are being explored.

EROMANGA BASIN, BY A. MOND & P. L. HARRISON (Geophysical Branch)

The Mesozoic Eromanga Basin, the largest of the group of basins that form the Trans-Australian Platform Cover, underlies an area of about 1 million km^2, and extends from 20°S to 32°S latitude and from 132°E to 147°E longitude. The objectives of recent work have been to broadly synthesize the geology of the Queensland and Northern Territory parts of the basin in the form of notes on the stratigraphy and structure accompanied by 1:1 000 000-scale geological, isopach, and structure contour maps. Texts and maps for the northern and central parts of the basin (Bulletins 167A, B) were completed by B. R. Senior and P. L. Harrison in 1974. The report and maps on the northwestern part (Bulletin 167C) were completed by A. Mond and P. L. Harrison in 1975.

Bulletin 167C covers that part of the Eromanga Basin north of 26°S and west of 141°E where the sequence consists of Lower Jurassic to Upper Cretaceous rocks underlain by older sedimentary basins and by crystalline basement, and overlain by Cainozoic sediments of the Lake Eyre Basin and other Quaternary deposits. The synthesis of the geology of the basin has shown that units of similar lithology and stratigraphic position have been given different names in various parts of the basin. To establish a common basis for future studies several names have been dropped and stratigraphic names used in central, northern and South Australian parts of the Eromanga Basin have been extended into the northwestern area.

Some aspects of the Eromanga Basin Project study were published separately and include papers for outside journals outlining the geology of the underlying Cooper Basin sequence and a review of the Cadna-owie and Toolebuc Formations in the Eromanga Basin in Queensland. A regional appraisal of the Cretaceous geology of the Eromanga and Surat Basins written in conjunction with N. Exon will be published early in 1976.

NGALIA BASIN, BY A. T. WELLS

The objectives of the Ngalia Basin Project are to complete reporting on field surveys in the Ngalia Basin, and to synthesize the information into a form suitable for publication as a Bulletin.

A report on new stratigraphic information from drilling in the Ngalia Basin is being issued as Record 1974/153.

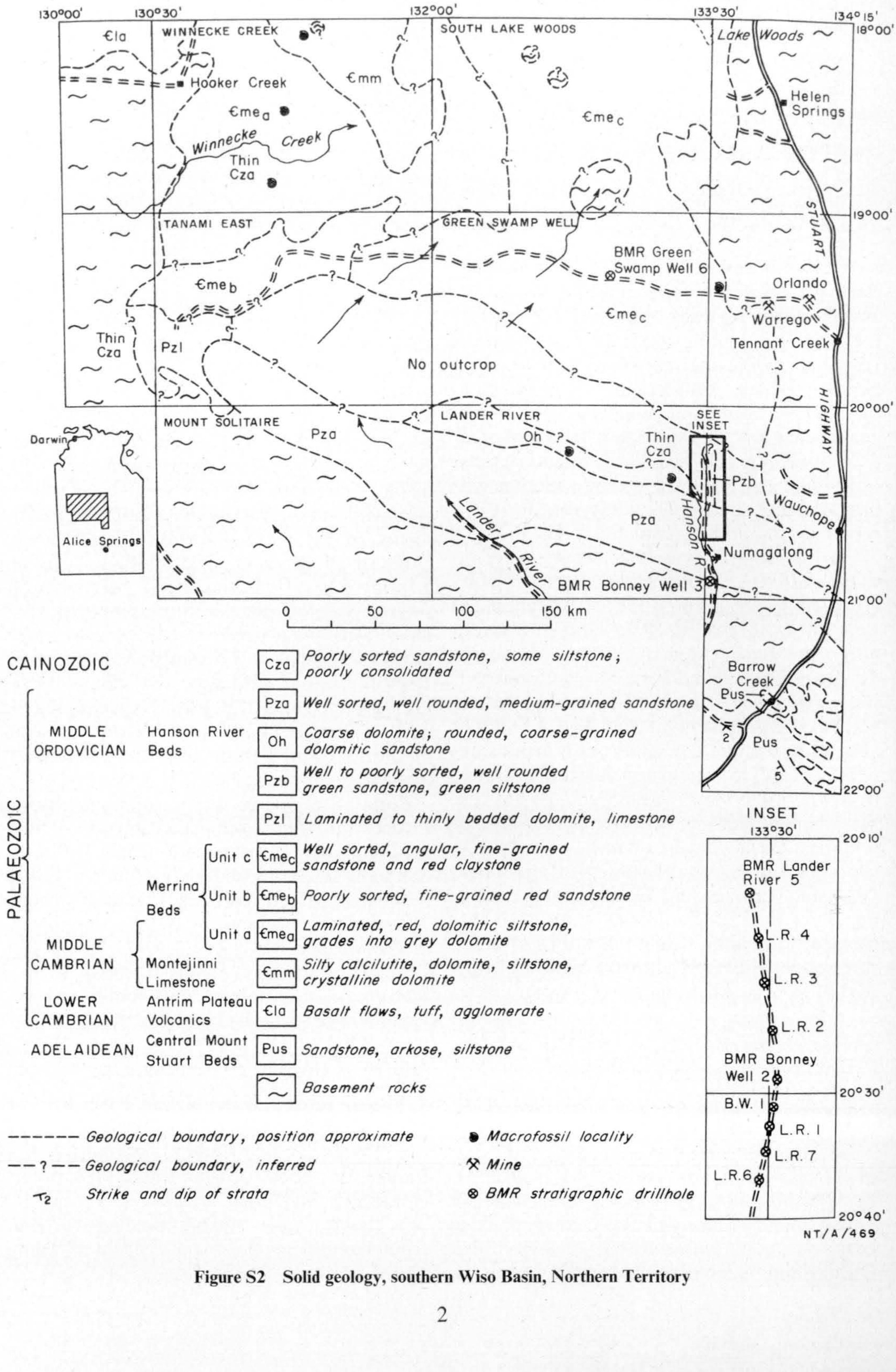

Figure S2 Solid geology, southern Wiso Basin, Northern Territory

Work continued on samples obtained during field surveys. A black shale of unknown stratigraphic position from BMR Napperby No. 5 drilled in the poorly outcropping eastern part of the basin was submitted for isotopic dating but the results were inconclusive.

Hydrocarbon analyses were carried out by D. M. McKirdy, of the Petroleum Technology Section, on carbonaceous drill core samples from the Carboniferous Mount Eclipse Sandstone. The sediments, of continental origin, gave hydrocarbon extracts with a predominance of even-over-odd n-alkanes above C_{20}; this pattern differs from that of sediments containing terrestrial plant matter that occur in paralic and near-shore environments, which are so common in petroleum source rocks elsewhere in Australia (D. M. McKirdy, pers. comm.).

WISO BASIN, BY P. J. KENNEWELL & M. B. HULEATT

STAFF: P. J. Kennewell, M. B. Huleatt, J. Gilbert-Tomlinson.

The objectives of the Wiso Basin Project are to produce Explanatory Notes and First Edition maps of the *WINNECKE CREEK*, *SOUTH LAKE WOODS*, *TANAMI EAST*, *GREEN SWAMP WELL*, *MOUNT SOLITAIRE*, and *LANDER RIVER* 1:250 000 Sheet areas. A publication on the geology of the south Wiso Basin, incorporating interpretation of geophysical data, is planned. Preliminary maps are available following a reconnaissance geological survey of the area in 1965 (Record 1966/47).

Ten shallow stratigraphic holes were drilled in the southeast part of the basin in 1974 and an additional one, BMR Green Swamp Well 6, was drilled to 337 metres in May 1975. Geological mapping was carried out in June and July 1975 by helicopter (95 hours). Results of mapping the Wiso Basin succession are given below. Basement rocks on the *MOUNT SOLITAIRE* and *LANDER RIVER* Sheet areas, mapped by the Metalliferous Section, are described later in this *Summary*.

The 1975 mapping and 1974-75 drilling results (synthesized in Fig. S2) indicate that basin structure is simple and that basement outcrops occur within the basin, and have allowed refinement of the rock units mapped previously.

Low and sparse outcrops, deep weathering, gradational contacts, and a paucity of macrofossils make separation of the rock units difficult. Seventy carbonate samples are being processed for conodonts as, if present, these fossils should provide valuable stratigraphic information. The distribution of rock units, as shown on the provisional solid geology map (Fig. S2), is based solely on field observation.

There is no evidence of significant folding of rocks exposed at the surface, and structural deformation must be slight if it is present at all. Although magnetic basement is deep in most of this area, sparse shallow anomalies (0 to 1000 m below sea level) are interpreted as indicating the base of the Phanerozoic sequence, which is probably underlain mainly by weakly magnetic rocks.

The structure in the area underlain by the flat-lying unit Pza is uncertain. Three shallow anomalies suggest that the Phanerozoic sequence is thin and overlies weakly magnetic rocks. A seismic survey, however, records south-dipping layered rocks up to 2000 m thick under part of this area. The contact of these rocks with the Arunta Complex crystalline basement to the south must be faulted, or steeply folded, with the structure concealed by the overlapping unit Pza. The nature and age of these sub-surface south-dipping rocks is not known. The Adelaidean Central Mount Stuart Beds dip gently to the southwest in the area south of Barrow Creek, and correlatives of these rocks may be present.

Previously unrecorded basement outcrops of Tomkinson Creek Beds (quartzite) in the *SOUTH LAKE WOODS* Sheet area and of Proterozoic quartzite in the *WINNECKE CREEK* Sheet area are shown. It is likely that basement rocks are concealed by a thin veneer of Phanerozoic sediments in parts of these areas.

The Montejinni Limestone (Cmm) extends into the area from the north and was penetrated by BMR Green Swamp Well 6, where it is in gradational contact with the overlying Merrina Beds.

The Merrina Beds, which consist of sandstone, claystone, dolomitic siltstone, and dolomite has been split into unit Cme_a containing lower Middle Cambrian fossils overlain with a gradational contact by two unfossiliferous and possibly laterally equivalent units, Cme_b and Cme_c.

The dolomite unit Pzl is flat-lying, topographically higher than the Merrina Beds, and probably overlies them; its age is unknown. Traces of malachite infill small cavities at one locality.

Unit Pzb, consisting of green sandstone and siltstone, is known only from the 1974 drilling in the Hanson River area.

The Hanson River Beds are flat-lying, overlie unit Pzb, and contain a Middle Ordovician fauna.

The stratigraphic relation between unit Pzl and the unit Pzb/Hanson River Beds sequence is not known because they are not in contact.

Unit Pza overlies the Hanson River Beds and appears to transgress the Arunta Complex at the southern margin of the basin.

Terrestrial deposits of unit Cza up to several tens of metres thick occur in several parts of the area. It is not known whether all occurrences are of the same age, but all are lateritized or extremely weathered.

BMR Green Swamp Well 6 penetrated 3 m of Quaternary sand and 183 m of Merrina Beds (21 m of Unit Cme_c and 162 metres of unit Cme_a) overlying 151 m of Montejinni Limestone to its total depth of 337 m. It is being deepened to basement.

The known diagnostic macrofossil localities are shown in Figure S2. Localities in *WINNECKE CREEK* and *TENNANT CREEK* Sheet areas yielded Cambrian fossils, and those in *LANDER RIVER* Sheet area yielded Ordovician fossils. Compared with the Amadeus Basin, the Cambrian fossils correlate with the trilobite band at the base of the Giles Creek Formation and the only diagnostic Ordovician fauna with the upper part of the Stairway Sandstone.

CANNING BASIN, BY A. N. YEATES & R. R. TOWNER

STAFF: A. N. Yeates, R. R. Towner, M. J. Jackson (24/6/75 to 15/7/75) J. M. Dickins (15/7/75 to 28/7/75); R. W. A. Crowe (GSWA).

The objectives of the project are to remap the Canning Basin in sufficient detail to enable the preparation of all outstanding 1:250 000 First Edition geological maps and Explanatory Notes. Second Edition maps and notes of some Sheet areas will be prepared if substantial new information becomes available. The project is a joint one with the Geological Survey of Western Australia and the Basin Studies Group of BMR. Field investigations began in 1972 and should be completed in 1977.

Northeast Canning Basin

Reporting of 1972-73 field work was completed in May as Record 1975/77. Descriptions of plant fossils by Mary E. White collected during the field work will be released shortly in the Records Series together with a map depicting a generalized interpretation of the solid geology at a scale of 1:1 000 000 compiled by Yeates.

The results of the 1974 mapping of the Permian of the *NOONKANBAH* 1:250 000 Sheet area are being prepared as a Record by Crowe and Towner.

The Preliminary Edition of *HELENA* 1:250 000 Sheet area has been released, and Preliminary Editions of *CORNISH* and *CROSSLAND* are well advanced; it is planned to issue *MOUNT BANNERMAN* and *NOONKANBAH* in 1976.

Explanatory Notes for *BILLILUNA*, *STANSMORE*, *DUMMER*, *HELENA*, and *WEBB* are with the editors; notes for *LUCAS*, *CORNISH*, *CROSSLAND*, and *MOUNT BANNERMAN* were completed and were being checked at the end of October.

A paper 'New and Revised Stratigraphic Nomenclature, Northeast Canning Basin' was accepted for publication in the GSWA Annual Report for 1974. A second paper entitled 'New Stratigraphic Nomenclature, Noonkanbah 1:250 000 Sheet area', which defined new members in the Grant Formation and Poole Sandstone, was submitted for publication in the 1975 GSWA Annual Report.

South Canning Basin

Between 20 June and 1 August, the party mapped *SAHARA*, *PERCIVAL*, *WILSON*, *URAL*, *RYAN*, *MORRIS*, and the Phanerozoic of *TABLETOP*, *RUDALL*, and *RUNTON* 1:250 000 Sheet areas by helicopter following examination of airphotos in April and May. M. J. Jackson joined the party for three weeks as he had previously mapped

TABLE S1. Pre-Cainozoic stratigraphy of the southern part of the Canning Basin

Age	*Rock unit and map symbol*	*Approximate exposed maximum thickness (m)*	*Lithology*	*Remarks*
CRETACEOUS-?TERTIARY	Lampe Beds (KTl)	5	Silicified quartzose sandstone, conglomerate	Unconformable on Ke, Ks, Mr, Pa and Precambrian
LOWER CRETACEOUS	Bejah Claystone (Ke)	5	Claystone, shale, siltstone, porcellanite	Gradational on Ks; unconformable beneath KTl, kaolinized, silicified; marine fossils, shallow marine
	Samuel Formation (Ks)	25	Siltstone, silty and quartzose sandstone; fossiliferous	Grades laterally into and lies on Kk; gradational beneath Ke; disconformable on Mr and beneath KTl; kaolinized; shallow marine
	Mx	10	Sandstone and granule conglomerate, quartzose	Lies within Kk and Mr with interfingering and irregular relationship; capped by laterite; fossil soil
	Kidson Beds (Kk)	50	Siltstone and fine quartzose sandstone, lenses of coarse quartzose sandstone and conglomerate; minor intraformational claystone conglomerate	Partly overlain by and laterally equivalent to Ks; gradational and sharp contact with Mr below; unconformable on Permian and Precambrian rocks; unconformable beneath KTl; laterally equivalent to and irregular contact with Mx. Rare wood fragments and *Rhizocorallium* burrows; non-marine
?UPPER TRIASSIC OR JURASSIC	Cronin Sandstone (Mr)	50	Quartzose sandstone, conglomerate; minor siltstone and intraformational claystone conglomerate	Unconformable on Pt, Pn, P and Pa; laterally equivalent to Mx; overlain with gradational and sharp contact by Kk; overlain disconformably by Ks. Plant-bearing in places, fluviatile
PERMIAN	P	unknown	Sandstone, siltstone, shale	Unconformable beneath Mr
LOWER PERMIAN	Noonkanbah Formation (Pn)	?	Sandstone, quartzose, micaceous and feldspathic; minor coarse sandstone, conglomerate	Unconformable beneath Mr; probably conformable on Pc or its equivalent in subsurface. Partly lateral equivalent of Pt and Pd; shallow marine
	Triwhite Sandstone (Pt)	70	Quartzose micaceous sandstone	Conformable on Pd; unconformable beneath Mr and Kk; partly equivalent to Pn. Fossiliferous; shallow marine
	Dora Shale (Pd)	5 (considerably thicker in subsurface)	Siltstone; shale, carbonaceous; silty coal; minor very fine silty sandstone	Conformable between Pc and Pt; equivalent to lower part of Pn; unconformable beneath Kk; ?non-marine
	Cuncudgerie Sandstone (Pc)	15	Quartzose sandstone, fine, well sorted, thin-bedded	Conformable between Pa and Pd and probably Pn; unconformable beneath Kk. Fossiliferous; shallow marine
	Paterson Formation (Pa)	100	Quartzose sandstone; silty sandstone; siltstone and shale, some with pebble to boulder-sized dropstones; tillite; varves; conglomerate	Unconformable on Precambrian and Pz; conformable beneath Pc; unconformable beneath Mr, Kk and KTl; shallow marine and fluviatile
PALAEOZOIC	Pz	?	Silty sandstone, fine to coarse; micaceous siltstone	Thought to be unconformable between Precambrian rocks and Paterson Formation, as in subsurface

PRECAMBRIAN	Undivided	?	Igneous, sedimentary and metamorphic rocks	Unconformable beneath Phanerozoic units; forms basement of Canning, Officer and Amadeus Basins

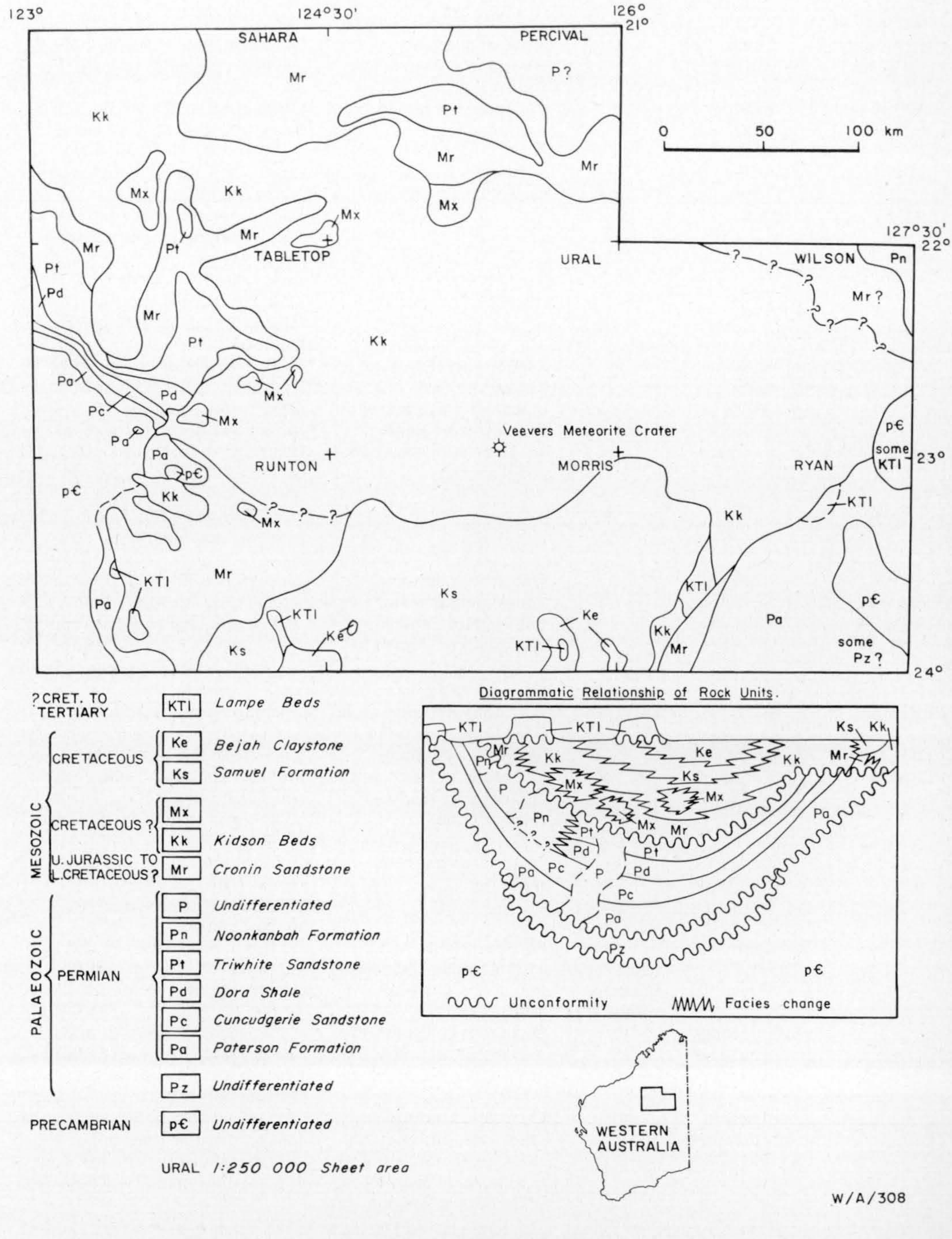

Figure S3 Solid geology, south Canning Basin, Western Australia (Cainozoic units omitted)

adjacent areas to the south. J. M. Dickins spent two weeks collecting Permian fossils. The Precambrian parts of *TABLETOP*, *RUDALL*, and *RUNTON* were mapped by GSWA.

A provisional interpretation of the solid geology is given in Figure S3. The stratigraphy of surface units is summarized in Table S1. At the end of October, work commenced on assessment of the subsurface geology from the results of subsidized geophysical surveys in the area, and on the compilation of the geology.

The mapping was done on 1:50 000 scale airphotos (1953) for *SAHARA* and *PERCIVAL* and 1:80 000 (1973) for the remainder. The main geological results are:

(1) The distribution of many rock units was considerably modified from that portrayed in existing reconnaissance geological maps.

(2) The previously mapped Anketell Sandstone in the area includes the Kidson Beds (mainly low-energy non-marine deposits) which pass laterally into and also underlie the marine Samuel Formation to the south. The Kidson Beds lie with both sharp and gradational (interfingering) contact on the widespread, high-energy fluvial deposits of the Cronin Sandstone. This suggests that the Lower Cretaceous marine transgression into the southern part of the Canning Basin came from the south. The sea was previously thought to have entered the area from the northwest. It also suggests the Cronin Sandstone may extend into the Lower Cretaceous.

(3) Revisions of stratigraphic nomenclature to be proposed include: redefining the Dora Shale; upgrading the Kidson Beds to formation status and the naming of a previously unrecognized unit (Mx in Fig. S3) interpreted as fossil soils.

(4) A relict Cainozoic drainage system which antedates the aeolian sand cover is preserved in the area; its wide distribution indicates that a much wetter climate existed in the past.

(5) The Canning Basin units on *RUDALL* (omitted in Fig. S3) consist of non-exposed Lower Permian in the northeast and outliers of Paterson Formation (glacial rocks interpreted as tillite, glaciolacustrine deposits and fluvioglacial deposits) preserved in fossil valleys that are incised into Precambrian rocks and which are presently being exhumed.

(6) The discovery of a new meteorite crater in southern *URAL*, with an outer diameter of 125 m and a depth of 7 m. Sheets of pisolitic laterite up to 30 cm thick form the rim of the crater, which dips at 10 to 15 degrees away from its centre and which rises up to 1.5 m above the surrounding sand plain.

OFFICER BASIN, BY M. J. JACKSON

STAFF: M. J. Jackson, P. J. Kennewell; W. J. E. van de Graaff (GSWA)

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 a 1:1 000 000 geological map, 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 1975 emphasis has been placed on completing outstanding Explanatory Notes and First Edition maps and eighteen of the twenty sheet areas have been finished (see frontispiece (1)). Six (*COBB*, *HERBERT*, *MASON*, *NEALE*, *SEEMORE* and *WARRI*) were issued during the year, and twelve are with the printers or editors. A start was made on the final (*ROBERT* and *WAIGEN*) Sheet areas.

No further progress has been made on the Bulletin or the accompanying 1:1 million map during the year.

A paper describing the results of regional geology, isotopic dating, and stromatolite studies on Proterozoic rocks from the western margin of the Officer Basin area was presented jointly (with Dr W. V. Preiss, SA Dept of Mines) to the First Australian Geological Convention. The results of this work show that a sequence of sedimentary rocks (now referred to as the Nabberu Basin), unconformably overlying the northeast margin of the Yilgarn Block, is early Proterozoic and not late Proterozoic as previously thought.

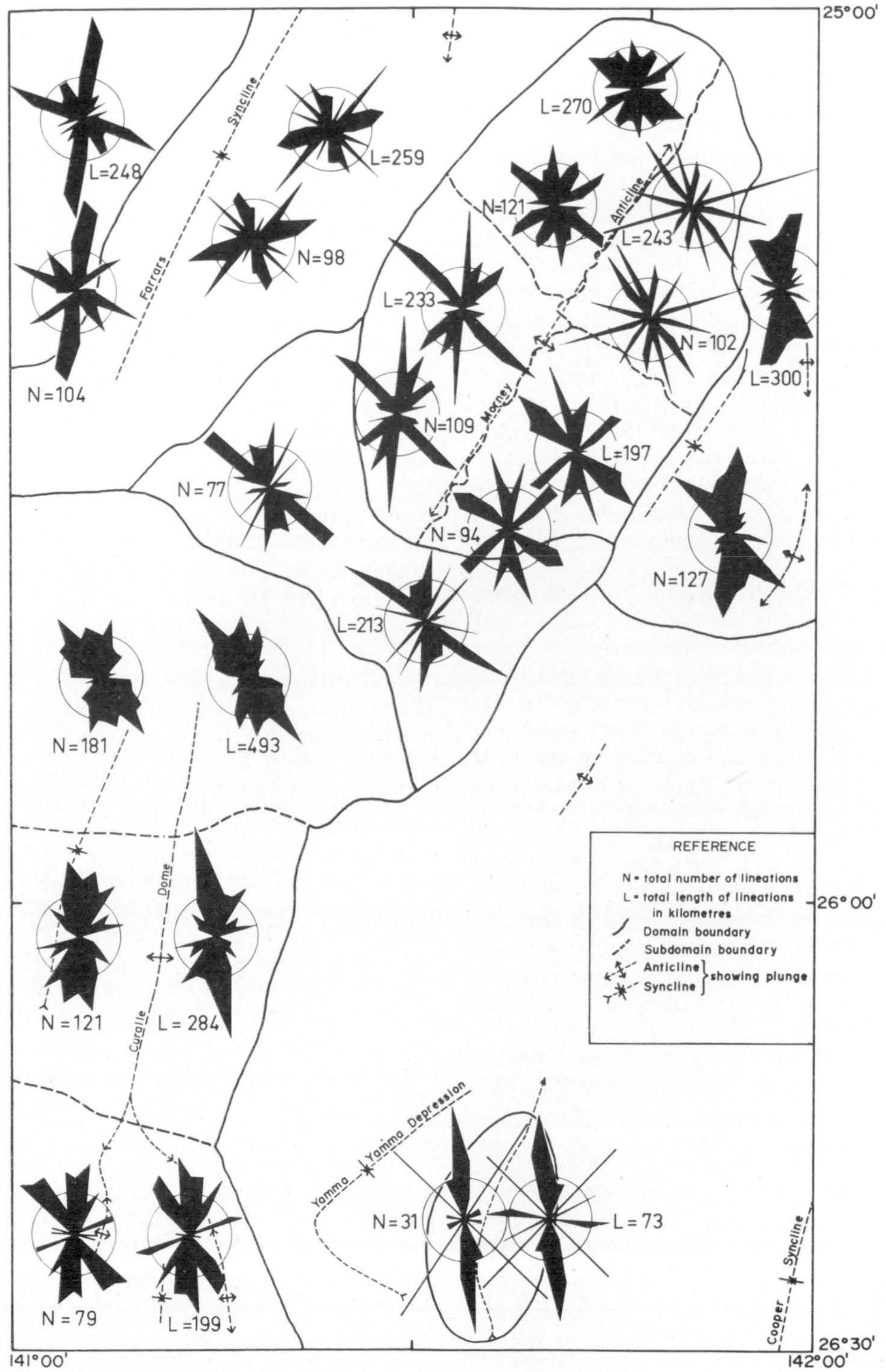

Figure S4 Low-order trend-analysis map of southwest Queensland study area, showing preferred orientations of photoscale lineations. Relative frequencies (%N) and lengths (%L) versus orientation directions (10° intervals) have been plotted in polar coordinates. The circle (radius 5.54%) represents a uniform distribution over all orientation directions

DETAILED MAPPING PROJECTS

SOUTHWEST QUEENSLAND GEOMORPHOLOGY, BY B. R. SENIOR

A study of chemical weathering processes, landform development, and neotectonics of the southwest Queensland region commenced in 1973. Within this region an area was selected for detailed study which encompasses the western portion of the *CANTERBURY* and *BARROLKA* 1:250 000 Sheet areas, between latitudes 25° and 26°30′S and longitudes 141° and 142°E.

During 1975, geochemical and clay mineralogical studies of hosts and weathered rock profiles continued. Using measured-section and geochemical data, four distinct mappable weathered rock profiles were identified in the region. The profiles that have been informally named, and for which reference (type) sections have been established, include the Morney and Canaway profiles and the Curalle and Haddon silcrete profiles. The Morney profile, which is particularly widespread, is up to 100 m thick in places, and extends across labile host rocks of the Rolling Downs Group from the central portion of the Eromanga Basin across the southern part of the Surat Basin in Queensland.

A map at 1:250 000 scale outlining the geology and geomorphology of the area studied in detail (Haddon Corner) was completed. This map gives detailed lithostratigraphic and physiographic divisions of component weathered profiles and associated Mesozoic and Cainozoic rock successions.

Structural interpretation of weathered rocks in the study area was achieved through a multidisciplinary approach. A study of linear features on RC9 aerial photographs and ERTS-1 imagery showed that the areas of weathered and unweathered rocks have abundant lineaments. These lineaments were statistically analysed in terms of percentage frequency and percentage length, and a low-order trend analysis map of the study area was compiled (Fig. S4). The information gained about regional and individual fold structures was compared with results of geological mapping and reconnaissance seismic surveys. ERTS-1 monochrome and false-colour imagery was found to be particularly useful in delineating fault traces invisible on conventional aerial photographs and previously detected only by seismic surveys.

Research carried out in conjunction with the Geophysical Branch includes a palaeomagnetic study of the ferruginous components of weathered rock profiles, and ground magnetic prospecting as an aid to precious opal exploration.

During July, 94 orientated samples for palaeomagnetic study were collected from the *MACHATTIE*, *CANTERBURY*, *BARROLKA*, *QUILPIE*, *EROMANGA*, *TOOMPINE* and *EULO* 1:250 000 Sheet areas. Units sampled include the Morney profile, Canaway profile and a ferralitic unit known as the Doonbara Formation. The purpose of this study is to determine the age of weathering events by relating the remanent magnetic declination and inclination data to the Tertiary polar wander curve.

In conjunction with C. L. Horsfall (Geophysical Branch) a Record was completed which outlines the geology of some Queensland precious opal deposits. This Record evaluates ground magnetic techniques as an aid to detecting subsurface concentrations of ironstone host rocks.

GEORGINA BASIN, BY E. C. DRUCE

STAFF: E. C. Druce, B. M. Radke, J. J. Draper, J. H. Shergold (part-time), M. R. Walter (part-time); P. West (ANU)

The Georgina Basin Project aims to improve the understanding of the geological history of the basin, particularly by elucidating the lithological and geochemical variations of units and their interelationships. It includes a detailed study of the biota to aid in correlation, and palaeoenvironmental and palaeogeographical reconstructions. The results will aid exploration for hydrocarbons, phosphate, and base metals.

Field work in 1975 was concentrated in the southern part of the Basin so that (i) the stratigraphy of the Field River Beds (Adelaidean) could be determined, the distribution of the lithofacies recognized, and the relationship with Lower Cambrian units elucidated (M. R. Walter); (ii) the distribution in space and time of the Arthur Creek and Marqua Beds (Middle Cambrian) could be outlined, and their lithofacies and depositional environment determined (P. W.

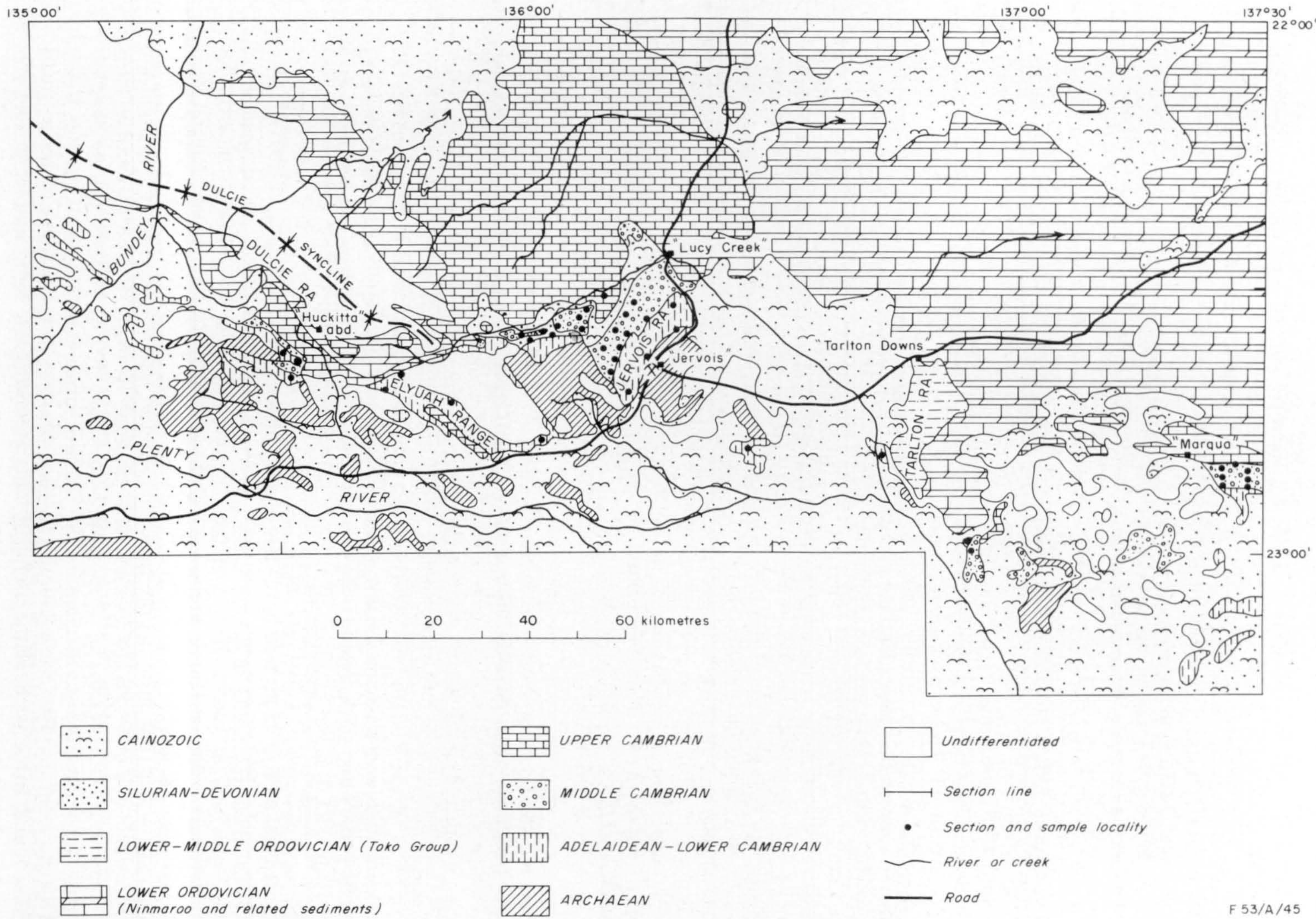

Figure S5 Sample and section locations, Tarlton-Huckitta area, Georgina Basin, Northern Territory

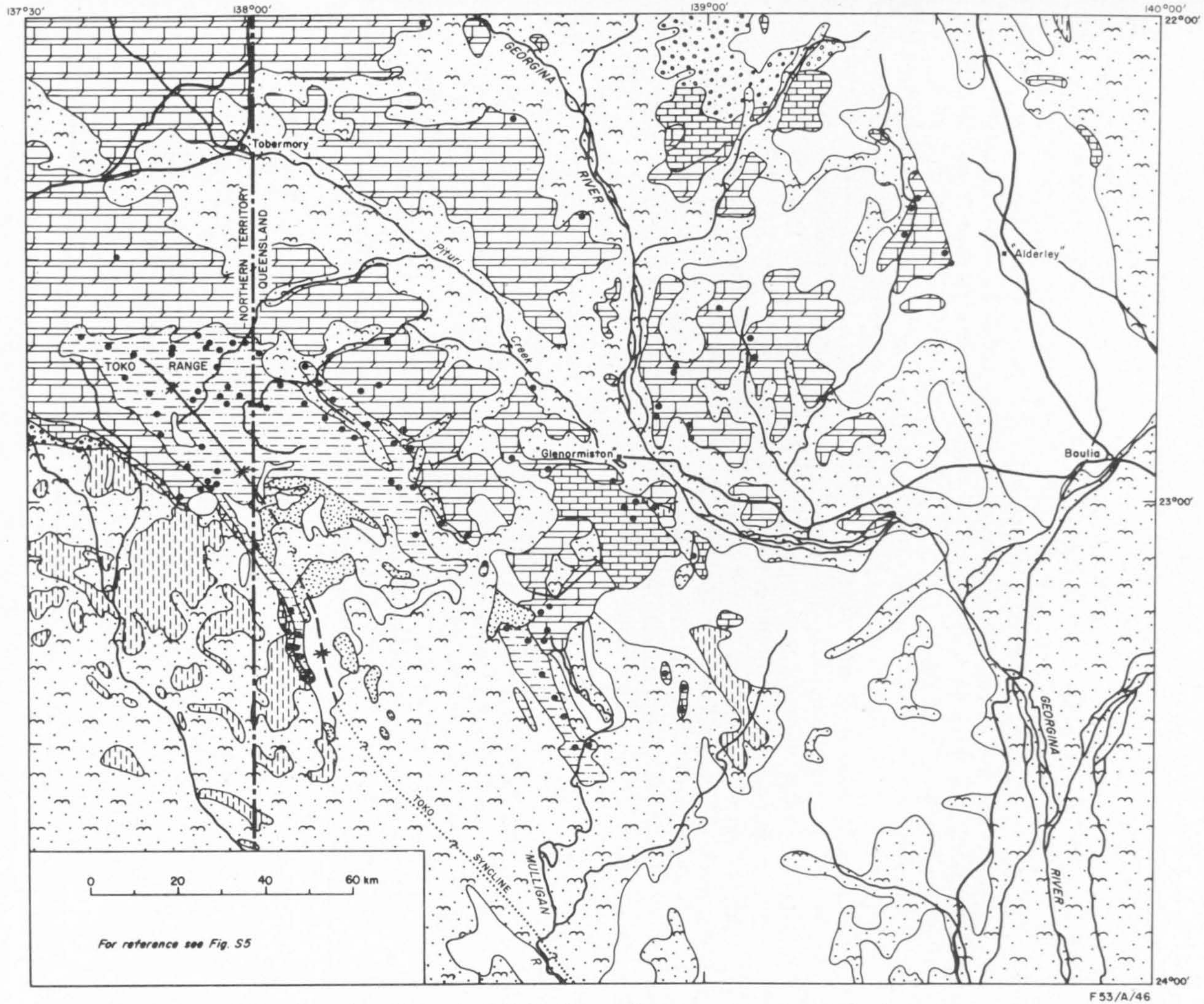

Figure S6 Locations of stratigraphic sections, Toko-Glenormiston area, Georgina Basin, Queensland and Northern Territory

West); (iii) the regional variations of the lithofacies of the Ninmaroo Formation (Upper Cambrian-Lower Ordovician) and its depositional environments could be determined, their extent in space and time could be outlined and their stratigraphic relation to other units evaluated (B. M. Radke); (iv) the regional variations of the lithofacies of the Kelly Creek Formation and the Toko Group (Coolibah, Nora, and Mithaka Formations and the Carlo Sandstone) could be determined (E. C. Druce and J. J. Draper).

Sections were measured and comprehensive samples were collected (Figs S5, S6).

Preliminary results indicate that

1. the Field River Beds (Adelaidean) can be divided into six distinct lithological units—a basal arkose unit nonconformably overlying granite (in at least one area), a dolomite unit, a glacigene unit, an arkosic unit, a dolomite unit, and at the top, an arkose;
2. the Field River Beds are overlain by the Grant Bluff Formation in the *HAY RIVER* 1:250 000 Sheet area, although the uppermost part of the latter is not exposed;
3. the vertical and inclined burrows in the Grant Bluff Formation in the *HAY RIVER* 1:250 000 Sheet area are similar to burrows occurring in the overlying Mount Baldwin Formation further west (Huckitta Sheet area);
4. the trace fossil sequence in the Mount Baldwin Formation suggests that the upper part at least is no older than Early Cambrian;
5. the glacigene unit of the Field River Beds can be correlated with the Olympic Member of the Pertatataka Formation of the Amadeus Basin; similarly the upper, ridge-forming arkose and the overlying Grant Bluff Formation are probably equivalent to the Arumbera Sandstone;
6. in the *HUCKITTA* and *TOBERMORY* Sheet areas sediments underlying the Grant Bluff Formation are valley-fill deposits in the metamorphic basement;
7. the Arthur Creek and Marqua Beds contain simila[illegible]lobite faunas to the Middle Camb[illegible]he eastern margin;
8. considerable and rapid facies changes are present in the Arthur Creek Beds;
9. the type section of the Ninmaroo Formation (Upper Cambrian-Lower Ordovician) at Mount Unbunmaroo consists of five members,
   (i) 165 m of thick-to medium-bedded intraclastic and peloid grainstone, mudstone, stromatolitic bioherms, and thin biostromes (algal bioherm activity contributed most of the detrital sediments which accumulated in restricted marine conditions) overlain by
   (ii) 210 m of thin-to thick-bedded peloidal and conglomeratic grainstones, micrite, stromatolitic boundstones with interbedded 'two-tone' limestone (algae provided the majority of the sediment which accumulated in quiet conditions and was subsequently bioturbated and diagenetically altered to 'two-tone'), overlain by
   (iii) 105 m of intraformational conglomeratic grainstone, ooid and peloid grainstones and stromatolitic boundstone biostromes (these conglomerates are derived both from exfoliation of algal mounds and the breakup of 'hardground' during high-energy periods with contemporary formation of ooids), overlain by
   (iv) 120 m of pelmatozoan grainstone, peloid, conglomeratic and ooid grainstone with minor dolomitic sandstone (deposition occurred in a high-energy environment with the accumulation of skeletal debris and sand into shoals), overlain by
   (v) 200 m of thin-bedded fossiliferous limestone, locally dolomitized, with interbedded secondary chert laminae, resulting from near-shore dolomitization and silicification of shallow-marine carbonates;
10. to the west of the Boulia area the sequence of members of the Ninmaroo Formation is generally similar al-

though significant variations occur, including an increased abundance of algal biostromes;

11. the Ninmaroo Formation contains traces of purple and yellow fluorite which occurs as vug fillings, commonly in the intraformational conglomerates and, in parts of the sequence, directly overlying dolomites. Pseudomorphs of sulphides (mainly pyrite) and traces of malachite have also been observed;
12. the Kelly Creek Formation (Lower Ordovician) is composed of three units: basal dolomite which is closely related to the Ninmaroo Formation, overlain by a fine-grained, cross-stratified, ripple-marked sandstone which is in turn overlain by a fossiliferous dolomite;
13. the basal dolomite of the Kelly Creek Formation was deposited in very shallow water with the development of herringbone cross-bedding; it is commonly deeply weathered with collapse of overlying sandstone into karst features;
14. pseudomorphs of sulphides (particularly pyrite) are commonly present in rubble development on the Kelly Creek Formation;
15. the Coolibah Formation (Lower Ordovician) consists of algal grainstones with interbedded calcareous siltstone; molluscs are abundant and the limestones are extensively bioturbated; concretions of pseudomorphs after pyrite are common;
16. the Nora Formation (Lower Ordovician) consists of five lithological units: a basal fine-grained sandstone with rare skeletal grainstone lenses, a skeletal grainstone with limonite clasts, a calcareous sandstone, a shale/siltstone, and an upper mollusc-rich sandstone;
17. the Carlo Sandstone consists of three distinct subfacies characterized by ichnofossils and sedimentary structures: the basal subfacies is characterized by *Cruziana* and flute casts, the overlying subfacies has a preponderance of grazing trails and burrows and is cross-stratified, and the uppermost subfacies is extensively bioturbated;
18. the Mithaka Formation is conformably overlain by an unnamed Ordovician sandstone with a fauna of trilobites, pelecypods, brachiopods, gastropods, and ichnofossils; sedimentary structures are similar to those at the base of the Carlo Sandstone;
19. the conglomerate near Mithaka Waterhole which had been assigned to the Cravens Peak Beds is a valley-fill unit which postdates the major deformation (?Carboniferous);

Analysis of geochemical results from the 1974 field program has demonstrated that the relative abundance of Zn (up to 2730 ppm) and Ba (up to 1.2 per cent) in the Swift Formation is due to concentration, together with Mn, in the weathering profile; and that the Upper Cambrian and Lower Ordovician rocks in the Burke River Structural Belt have extremely low phosphate values compared to the Middle Cambrian rocks in the same area.

TANTANGARA-BRINDABELLA, BY M. OWEN & D. WYBORN

The objectives of the Tantangara-Brindabella Mapping Project are to assist in the revision of the *CANBERRA* 1:250 000 Geological Sheet, to provide basic information for engineering geological investigations, and to obtain a better understanding of the igneous activity and mineralization of the area.

Mapping was completed in 1974, preliminary editions of the *TANTANGARA* and *BRINDABELLA* 1:100 000 sheets are available, and a description of the geology of the *TANTANGARA* Sheet area is in press (Record 1974/176). Field work during the past year has been limited to short trips to collect further geochemical and geochronology samples from important igneous units.

Geochronology results from Amdel include K-Ar ages of 455 $\pm$ 10 m.y. for a basic intrusion south of Happy Jacks Pondage (indicating that it is of Ordovocian age and probably related to the Nine Mile Volcanics), 430 $\pm$ 9 m.y. for the Micalong Swamp Basin Igneous Complex, 413 $\pm$ 8 m.y. for the Jackson Granite, 415 $\pm$ 8 m.y. for the Burrinjuck Adamellite and 15.2 $\pm$ 0.3 m.y.

for a basalt from Shannons Flat. The age of the Jackson Granite is of particular interest since it clearly intrudes the Early Devonian Mountain Creek Volcanics and is therefore of value in dating the Siluro-Devonian boundary. The Mountain Creek Volcanics unconformably overlie the Wenlockian to Pridolian Cooleman Limestone, and an outlier of Mountain Creek Volcanics (Pilleuil Andesite and Waynes Knob Rhyolite) overlies Gedinnian (Early Devonian) Elmside Formation near Yass (Link, A. G., 1970—*J. geol. Soc. Aust.* 16, 711-22). Further dating work, by Rb-Sr methods, is in progress to enable the age of the boundary to be better estimated.

An important result of the geochemical work has been the recognition of a suite of granitic rocks not previously recognized in the Lachlan Fold Belt. Chappel and White (*Pacific Geol.* 8, 173-4, 1974) have divided the Siluro-Devonian granites of the southern Lachlan Fold Belt into two chemically distinct groups, I-type and S-type granites. The S-type granites are thought to have been derived by partial melting of sedimentary rocks and the I-type granites by partial melting of mafic igneous rocks. The I-type granites are abundant only east of the area mapped (White, A. J. R., & Chappell, B. W., 1974—*Abstracts, Specialist Group Meeting, Geol. Soc. Aust., Brisbane*, 40-41; White, A. J. R., Chappell, B. W., & Cleary, J. R., 1974—*Pacific Geol.* 8, 159-71). The current mapping has shown there to be a belt of granitic and associated volcanic rocks in the Kosciusko, Tantangara, and Brindabella 1:100 000 Sheet areas which are similar to I-type granites using only the chemical and isotopic criteria specified by Chappell & White (*Pacific Geol.* 8, 173-4, 1974), but which occur well to the west of any other recognized I-type granites and have different trace element geochemistry. We have called this suite the KI-type granites. A comparison of the major element chemistry of the KI-type and normal I-type granites is shown in the following analyses:

	Average **KI-type*	*Average* *†normal I-type*
SiO_2	65.92	65.74
TiO_2	0.50	0.50
Al_2O_3	14.38	15.47
Fe_2O_3	1.70	1.47
FeO	2.82	3.02
MnO	0.09	0.09
MgO	2.63	2.16
CaO	4.27	4.80
Na_2O	3.00	2.86
K_2O	3.24	2.31
P_2O_5	0.14	0.11
H_2O^+	0.61	1.06
H_2O^-	0.15	0.11
CO_2	0.14	0.05
Total	99.59	99.75

*KI-type—average of 21 samples with a range of 60-73% SiO_2 (BMR samples)

†Normal I-type—average of 19 samples with a range of 60-72% SiO_2 (normal I-type average derived from 10 BMR samples from the *TANTANGARA* and *MICHELAGO* Sheet areas and 9 samples from the *BERRIDALE* Sheet area, taken from Williams (*unpubl. Hons. Thesis, A.N.U.*, 1972))

The averages show that the KI-type granites are significantly richer in K_2O, richer in MgO, Na_2O and P_2O_5 and poorer in Al_2O_3 and CaO. Figure S7 compares the average trace elements of the same two sets of samples. Compared to the average normal I-type granite the average KI-type granite has more than twice the abundance of Sr, Ba, and Cu, much higher Ni, Pb, Cr, and V, higher La, Ce, Zr, Rb, and K/Rb, lower Zn, and much lower Ca/Sr. The average KI-type granite is enriched in both the incompatible elements and most transition metals.

Regional reconnaissance indicates that the KI-type granite belt extends north and probably includes the Eugowra Granite and the Yeoval Batholith (Gulson, B. L., 1972—*Contrib. Minerals Petrol.* 35, 173-92) and possibly the Bogong Granite and Killimicat Adamellite. The KI-type belt is spatially related to the earlier, Ordovician Molong Volcanic Arc, a factor which may have some bearing on the distinctive KI-type chemistry.

The recently published Preliminary Edition of the *CANBERRA* 1:250 000 aeromagnetic map in most cases clearly distinguishes the strongly magnetic KI-type and normal I-type granites from the weakly magnetic S-type granites.

AMADEUS BASIN I. G. C. EXCURSION MAPPING, BY A. T. WELLS & J. M. KENNARD

The objective of the project was to plan a route and itinerary for the I.G.C. Amadeus Basin excursion. About 400 oblique colour photographs were obtained of the prominent structures in the central fold belt, northern margin and southern inselbergs, and were subsequently filed in the BMR Library. Large-scale vertical colour photographs were taken by the Airborne Group over 23 selected areas. Nominal negative scales in 70-mm format are 1:81 000 and 1:48 000, and prints produced at about twice negative size (23 cm) were used for detailed mapping of key areas along the route. An excursion guide was written and detailed sketch maps for use during the excursion were prepared.

An air-reconnaissance was undertaken to plan a flight path over the basin for the excursion.

Miscellaneous projects connected with the excursion included the investigation of magnesite deposits at Gosses Bluff, recompilation of the Phanerozoic stratigraphy on the southern part of the *HERMANNSBURG* 1:100 000 Sheet area, a brief investigation in the field of anomalous areas on Skylab infrared imagery over part of the Basin, and investigations of anomalous breccia zones in the Ordovician Pacoota Sandstone. The breccias, probably of sedimentary origin, are superficially similar to olistostrome deposits.

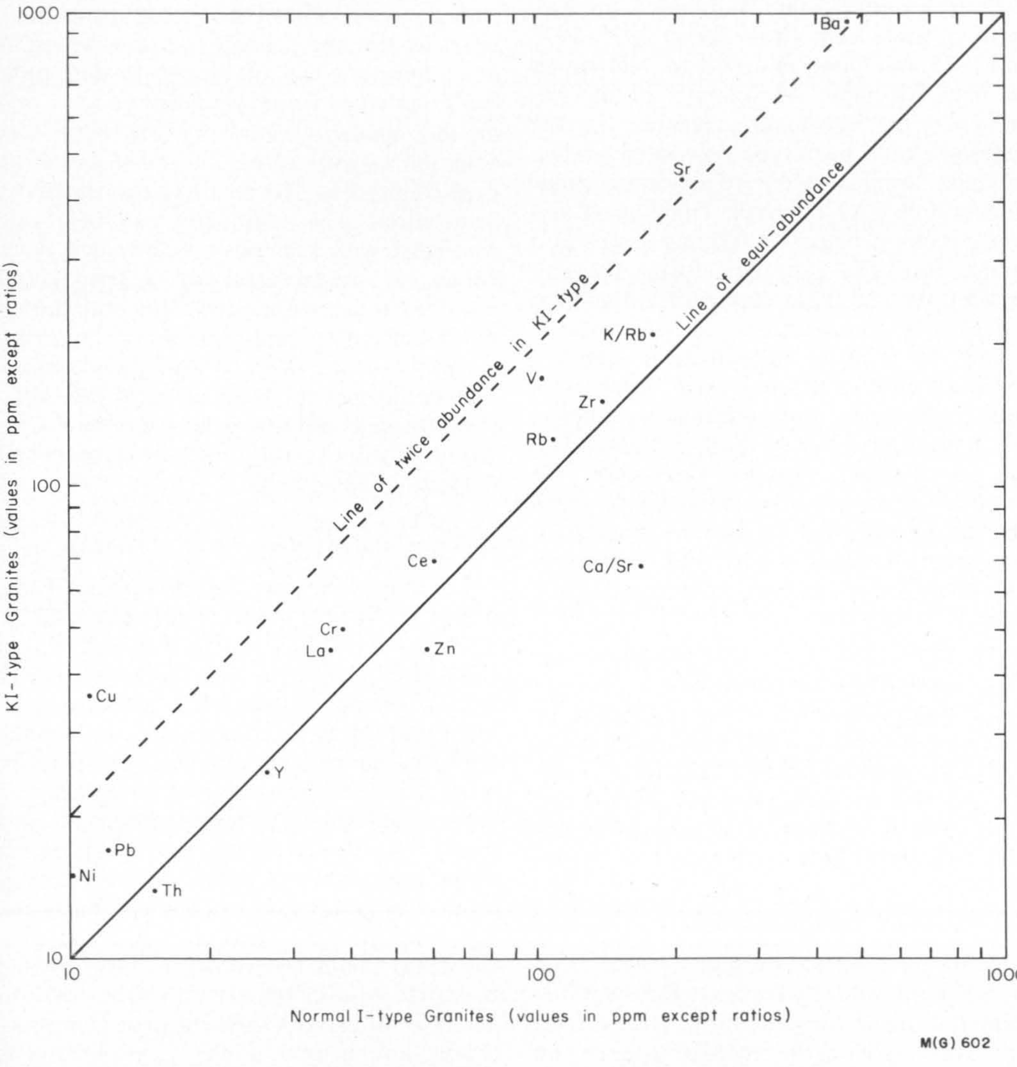

Figure S7 Comparison of average trace-element values for KI-type and normal I-type granites, Tantangara-Michelago-Berridale region, southern New South Wales

GREAT ARTESIAN BASIN, BY M. A. HABERMEHL & G. E. SEIDEL

STAFF: M. A. Habermehl, G. E. Seidel; M. Audibert (BRGM) until May 1975

The aim of the hydrogeological study of the Great Artesian Basin is to develop an assessment, management, and prediction tool for the basin's artesian groundwater resources. A digital computer model, based on finite difference approximations of the Hantush approach for leaky artesian aquifers, was selected for this purpose.

Hydrogeological data transcribed from records of State authorities during 1972, 1973 and 1974 were punched, checked, and stored on magnetic tape. An analysis of the hydrogeological information resulted in the definition of a prototype consisting of two confined aquifers CA1 (Cretaceous sandstones) and CA2 (Jurassic sandstones) and two confining beds (Cretaceous shales and mudstones). 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 on the GAB-ADP system. Following the definition of the prototype, model parameters had to be adjusted to achieve maximum agreement between model and prototype. This process of calibration commenced in late 1974. During 1975:

(1) calibration by conventional means (trial and error) continued;
(2) a direct solution of the calibration by inverting the model was developed;
(3) the original model GABSIM was adjusted and errors removed from it; and
(4) a new system of model programs (GABHYD) was developed.

Calibration by conventional means

Hydrodynamic parameters derived from sparse point values were used for an initial computation of the potentiometric surface, which differed from the recorded values by up to 180 m. Systematic variations of the hydraulic parameters reduced this error to 45 m, or about 10 per cent of the total piezometric head, but later improvements were only marginal and often accompanied by deterioration of values in areas adjoining those where the hydraulic parameters had been corrected. No better results could be achieved by the conventional trial and error method of calibration.

Calibration by model inversion

This direct approach was introduced after substantial changes to the original model program GABSIM. Alterations applied included replacement of the average transmissivities by directly defined transmissivities. A new algorithm was developed to determine transmissivities from the distribution of hydraulic heads by applying the continuity equation to pairs of model grid nodes in an iterative process. The resulting transmissivity distribution was reasonably uniform and consistent with previously determined point values. A model error of a few metres occurred at some nodes near the boundaries, but elsewhere the reproduction of the potentiometric surface of the prototype was exact. This completed the calibration of the initial steady-state condition, which represents conditions prior to substantial development of the basin (1880-1900).

Adjustment and correction of GABSIM

Computer memory requirements of the original GABSIM model greatly exceeded the resources available on the CYBER 76 of CSIRO in Canberra. Several modifications had to be applied together with program segmentation to accommodate the model. However, as segmentation was not operative on the CYBER 76, a system of storage sharing between variables had to be introduced. As a result of this and in spite of previous program simplifications the GABSIM model required an unacceptable amount of computer processing time. It also became apparent that GABSIM could not simultaneously predict hydraulic heads and artesian flows at grid nodes. Redesign of GABSIM proved impracticable and a new model GABHYD was designed in BMR to replace the original model.

Design of the GABHYD model

GABHYD is a system of programs consisting of units of minimal interdependence connected by standardized data files. A minimum number of operations is performed by the model program itself, leaving the majority of input, calibration, data manipulation, and output operations to the separate units which are easily exchangeable. As a result of these design principles GABHYD requires significantly less computer memory than is available on the CYBER 76, and processes 15 times as fast as the GABSIM model. Key programs of the new system have been written, checked, and applied, successfully reproducing the results of the previous steady-state calibration. The non-steady state was simulated for the period 1900 to 1902 by using some experimental storage coefficients. Work is proceeding on the remaining programs of the GABHYD system, including units which will extend the direct calibration approach to the determination of storage coefficients, and so complete the non-steady-state calibration. After completion of the calibration phase the model will be ready for application.

Documentation

A progress report was prepared on the definition of the prototype and the input data, and the accompanying figures have been drafted. Writing commenced on a report on the hydrogeology of the Great Artesian Basin.

The contract with BRGM (Australia) for assistance in the hydrogeological study of the Great Australian Basin was completed during the year.

STUDIES OF GROUNDWATER MOVEMENT IN THE GREAT ARTESIAN BASIN USING ENVIRONMENTAL ISOTOPES, BY M. A. HABERMEHL

Isotopes in the groundwaters of the Great Artesian Basin are being studied by the Australian Atomic Energy Commission using information provided by BMR with the aim of elucidating the origin of the water, its residence time, and its rate of flow through the aquifers.

During 1974 and 1975, officers of AAEC collected samples from 82 flowing and non-flowing artesian waterwells in the basin, and analysed these for the naturally occurring radioactive isotope Carbon^{14}, the ratio of the stable isotopes of carbon (C^{13}/C^{12}), the hydrogen isotope ratio (D/H), the oxygen isotope ratio (O^{18}/O^{16}), the uranium isotope ratio (U^{234}/U^{238}), uranium concentration, and chemical constituents. The wells sampled were selected on hydrogeological criteria by BMR, and located along the groundwater flowlines in the Jurassic aquifers in a pattern radiating outwards from the main recharge area near Tambo and Augathella in Queensland.

Sampling during 1974 took place on a reconnaissance basis by sampling 45 wells along five radiating lines up to about 300 km from the major recharge areas. Results from isotope analyses showed that the C^{14} dating could be effectively applied only to a much smaller distance (about 150 km), which was in agreement with hydrodynamic computations.

In 1975, sampling was concentrated in a small area northeast of Augathella, adjoining the outcrop area of the aquifers, and along three traverses between this recharge area and the region between Eulo and Hungerford near the New South Wales border where there are a number of mound springs. Analysis of the samples from these 38 wells is continuing.

Results of calculations of hydrodynamic test data show that the average velocity of groundwater movement in the aquifers in this area amounts to less than 5 m/year. Preliminary results of the analysis of hydrogeological, isotope ratio, and hydrochemical information obtained from wells in this area, were highly compatible. They confirm the existence of an onlapping sequence, and a wedging-out of the lower aquifers and confining beds against the southward-rising shallow hydrogeological basement. They also indicated the probable movement of higher-quality water from the lower Jurassic aquifers into the overlying upper Jurassic-Cretaceous aquifer which contains more saline water of lower quality.

In the area north of Blackall the effects of recharge influxes could be distinguished by the isotope ratio and chemistry values.

WIRELINE LOGGING OF WATERBORES IN THE GREAT ARTESIAN BASIN, BY M. A. HABERMEHL

STAFF: M. A. Habermehl, J. Morrissey

The objective of the well logging program is to geophysically log existing waterwells in the Great Artesian Basin to obtain information on the subsurface geology and hydrogeology. As all the existing waterwells in the basin have been cased for most or all of their total depths, the geophysical work is mainly restricted to nuclear logs. The standard set of logs obtained from waterwells in the basin in this program consist of natural gamma-ray, neutron, differential temperature, temperature, and casing collar locator logs, and from some artesian wells a flow-meter log. If sufficient open hole occurs, electric and caliper logs are also run. The data obtained can be interpreted to determine the lithology, geometry, and total porosity of lithological units, to identify and correlate stratigraphic units and water-bearing beds, to define the source and movement of water discharged by the aquifers, and to determine construction and corrosion details of the casing in the well.

Since the commencement of well logging in the Great Artesian Basin in 1960, nearly 1200 waterwells including some converted petroleum exploration wells in Queensland, New South Wales, and the Northern Territory have been logged by BMR and its contractors; the results have greatly improved the geological knowledge of most parts of the basin, and more recently, assisted in the hydrogeological study of the Great Artesian Basin.

Forty-five non-flowing artesian wells, and artesian wells which had ceased flowing, in the eastern and southern part of the Surat Basin and the Coonamble Embayment in New South Wales were logged during November and December 1974 by Down Under Well Services Pty Ltd (Agnew-Go-Western Pty Ltd) under contract to BMR. Natural gamma-ray, neutron, temperature, differential temperature, and casing collar locator logs, as well as one electric log were obtained at scales 1 inch to 100 ft (1:1200) and 1 inch to 20 ft (1:240) (Table S2). This represents a total logged interval of 64 721 ft (19 726.9 m) or about 87 percent of the accumulated total depths of 73 686 ft (22 459.5 m) of these wells. Water samples were collected from 33 of the wells logged, and were analysed by the Chemical Laboratory of the N.S.W. Department of Mines.

In addition, the Geophysical Branch of BMR logged during April and May, 1975, twelve waterwells in the southern and western parts of this area, producing the same type of logs at similar scales for a total logged interval of 13 444 ft (4097.7 m) (Table S2A). Seven of the wells logged have been sampled and chemical analyses prepared by the N.S.W. Department of Mines.

BMR's Geophysical Branch logging unit continued work during May and June 1975 in the southern part of the Eromanga Basin in New South Wales, and logged 39 waterwells. Total depths of these wells amount to 59 661 ft (18 184.7 m) (Table S2B). Sixteen wells had water samples taken and chemical analyses were prepared by the N.S.W. Department of Mines.

The geophysical logs produced, in combination with drillers' logs from the Water Conservation and Irrigation Commission of New South Wales, enable an identification and correlation of lithostratigraphic units and aquifers in the Lower Cretaceous and Upper Jurassic sedimentary sequence in these parts of the Great Artesian Basin. In addition to the 96 wells logged by BMR and its contractor in 1974 and 1975, about 235 (mainly artesian) wells have been logged during the period from 1969 to 1974 by the Geological Survey of New South Wales in the Great Artesian Basin in that State, resulting in a fairly good coverage of subsurface information data points.

In September 1975 BMR commenced logging the waterwells in Queensland, which earlier had been sampled by the Australian Atomic Energy Commission (see previous section). These wells are in the region around Charleville, and tap Lower Cretaceous and Jurassic aquifers, in which the groundwater movement is directed from the recharge area near Tambo towards the area near Eulo and Hungerford, where mound springs exist. Other wells, sampled by AAEC located west and northwest of the aquifer outcrop areas, were also logged.

The checking and compilation continued of data on the wells logged since the commencement of logging in 1960. Basic well data, the types of logs run, log data, stratigraphical and hydrogeological information obtained, and

TABLE S2. Wireline logging of waterwells in the Great Artesian Basin; results obtained in New South Wales, 1974-75. Depths in feet

1:250 000 map sheet		Wells logged	Total depths of wells	Total intervals logged	Logs obtained G	N	T	C	E	Minimum total depth	Maximum total depth	Minimum interval logged	Maximum interval logged	Water sample and analysis
INVERELL	SH56-5	12	21 820	20 158	12	10	12	12	1	500	3 354	445	3 331	8
MOREE	SH55-8	8	15 705	12 638	8	7	8	8	—	1 091	2 794	508	2 762	6
NARRABRI	SH55-12	8	10 272	9 584	8	7	8	8	—	880	2 073	865	2 055	7
GILGANDRA	SH55-16	2	2 923	1 989	2	2	2	2	—	1 100	1 823	945	1 044	2
NYNGAN	SH55-15	15	22 966	20 352	15	15	15	15	—	968	2 203	538	2 106	10
		45	73 686 (22 459.5 m)	64 721 (19 726.9 m)	45	41	45	45	1					33
TABLE S2A														
NYNGAN	SH55-15	3	4 731	4 309	3	3	3	3	—	1 342	1 500?	1 146	1 646	3
WALGETT	SH55-11	8	9 211	8 300	8	8	8	8	—	661	1 740	315	1 673	4
ANGLEDOOL	SH55-7	1	850	835	1	1	1	1	—	850	850	835	835	–
		12	14 792 (4 508.7 m)	13 444 (4 097.7 m)	12	12	12	12	—	727				7
TABLE S2B														
MILPARINKA	SH54-7	5	8 232	7 143	5	5	5	5	—	1 163	2 318	1 164	1 680	3
URISINO	SH54-8	27	43 698	35 910	27	27	27	27	—	1 190	2 552	440	2 482	8
WHITE CLIFFS	SH54-12	7	7 731	7 404	7	7	7	7		727	1 232	621	1 248	5
		39	59 661 (18 184.7 m)	50 547 (15 379.2 m)	39	39	39	39	—					16

G—gamma-ray, N—neutron, T—temperature and differential temperature, C—casing collar locator, E—electric.

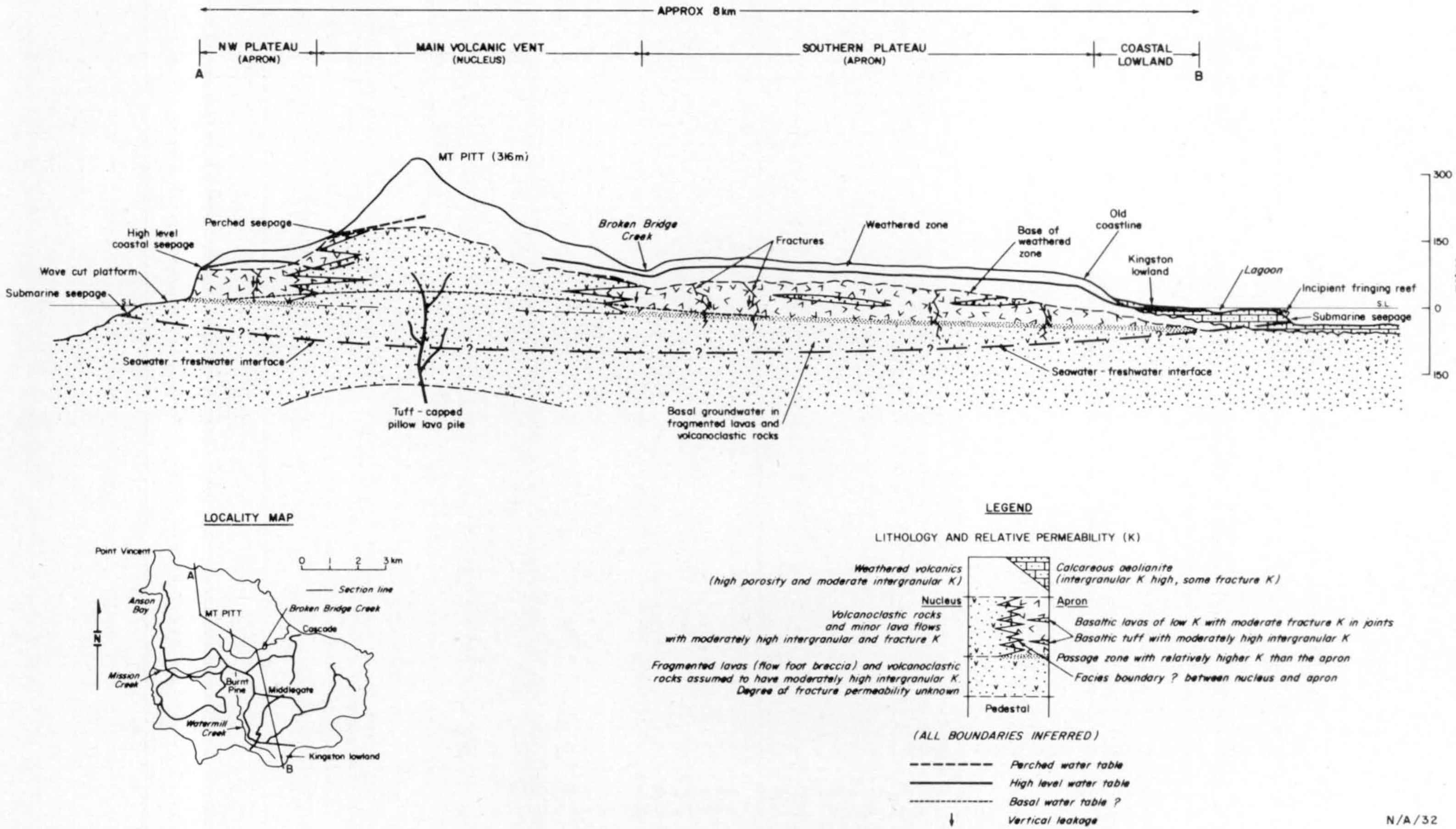

Figure S8 Schematic hydrogeological section across Norfolk Island

the results of chemical analysis of the water were transcribed and will be incorporated in a computer-based ADP system.

HYDROGEOLOGY OF NORFOLK ISLAND, BY R. S. ABELL

Geology

Norfolk Island is a deeply weathered erosional remnant of a volcano that erupted several times from 3.05 to 2.3 m.y. ago. The unweathered volcanic sequence is made up of flat-lying interbedded lava and tuff. Along the shore of the Kingston lowland are flaggy, calcareous aeolianites that support an incipient fringing coral reef.

Structurally Norfolk Island consists of a nucleus and an apron (Fig. S8). The nucleus corresponding to the main volcanic focus around Mount Pitt and Mount Bates is composed mainly of tuff, agglomerate, breccia, and thin basalt lava flows. The apron is a deeply dissected plateau making up the southern half of the island and a small part of the northwest. It is a constructional feature built up around the nucleus comprising basalt lava flows and local basaltic tuff. The boundary between the nucleus and the apron probably consists of interfingering lava and fragmental rocks.

A deep weathering profile up to 75 m thick has developed in the volcanic succession under the sub-tropical weathering conditions. The main residual products are lateritic soils (krasnozems), clay, spheroidal basalt, and decomposed volcanic rocks.

Hydrogeology

On Norfolk Island rainfall reaching the ground is either returned to the atmosphere by evapotranspiration or it infiltrates through the porous soil cover and moves downward under gravity past the root zone to the water-table. Where the ground surface intersects the water-table, groundwater discharges from valley sides as seepages, and flows to the margin of the island as streamflow. The remainder of the groundwater in the weathered zone passes through fractures in the unweathered portion of the volcanic sequence to the base of the island from where it eventually discharges to the sea as submarine seepages.

The highest underground water storage on the island is an unconfined aquifer in the weathered zone. The products of weathering which are porous and moderately permeable have considerable groundwater storage capacity and support a water-table with elevations exceeding 100 m above sea level. The configuration of the main water-table in the nucleus is largely unknown. From the little data available there is a suggestion of a groundwater mound influenced to a large degree by the topography and permeability of the underlying rocks. The nucleus supports a perched water-table over part of its northern and eastern slopes. Most bores and wells tap almost exclusively groundwater in the weathered zone. Out of a total of 295 groundwater extraction points about 60 per cent are presently in use, commonly ranging in yield from 500 to 1000 litres/hr.

Since fractures mainly control the movement of groundwater in the unweathered part of the volcanic sequence they should reflect zones of increased permeability, weathering, and solution and provide favourable drilling sites for water supplies. A preliminary fracture trace analysis suggests that fractures are mainly steeply inclined joints or zones of closely spaced joints which also influence the drainage pattern of the island. Most fractures have a preferred orientation in a NNW or ENE direction. Most bores are sited between fracture zones, and the few that occur within fracture zones tend to have either high or low yields, indicating that in the upper parts of these zones fracture permeability may be controlled by clay from the weathered zone. Fractures that trend NNW are the longest and most numerous and would have significance for water supply purposes if intersected by fractures that trend ENE. According to local information offshore springs occur close to Point Vincent. These springs are in line with NNW fractures, which supposedly confirms their importance as conduits for groundwater movement.

Intergranular permeability occurs in fragmental rocks associated with the nucleus and in calcareous aeolianite underlying the Kingston lowland. Samples of basaltic tuff subjected to poroperm (porosity-permeability) tests showed good storage capacity (20-40 per cent porosity) and good hydraulic conductivity (up to 7.2 m/day). Poroperm values for aeolianite show porosity ranging between 2 and 25 percent and hydraulic conductivity up to 1.2 m/day. The poroperm values of these rocks suggest they could store and transmit groundwater provided their subsurface extension is suitable.

Basal groundwater

According to a structural model of a marine basaltic volcano proposed by J. G. Jones (*Bull. Geol. Soc. Amer.*, 81, 1601-3, 1970) a permeability contrast is likely to exist beneath Norfolk Island at almost sea level (Fig. S8). A passage zone about 3 m thick of hackly jointed and fragmented lava represents a zone where subaerial lava was altered to flow-foot breccia as it flowed from air into water. These rocks are well exposed on the north side of the island between Anson Bay and Cascade and appear to have a higher permeability than the subaerial lava sequence. Below the passage zone, flow-foot breccias extend to an unknown depth, but because of their fragmented nature are assumed to have poroperm values similar to basaltic tuff. The nature and geometry of a possible freshwater lens is more likely to be controlled by groundwater conditions in the main vent, where the continuous succession of volcaniclastic rocks has a higher permeability than the plateau lavas. The basaltic lava sequence underlying the southern plateau can be considered as a semi-confining layer which has an overall permeability lower than the weathered zone except locally along fractures or where flows are interbedded with tuffs. In these conditions the high water-table elevation on the plateau will have little effect on basal groundwater, especially as groundwater movement through fractures is slow and basaltic tuffs may function as local groundwater storages.

An apparent lack of surface runoff and coastal seepages near sea level suggests that there is probably a strong vertical component to groundwater movement. A water balance study using long-term hydro-meteorological data suggests that after the needs of streamflow, evapotranspiration, and coastal seepage losses, a groundwater surplus of 6.3 $\times$ 10^6 m^3 annum is available to accumulate as basal groundwater providing there is an appropriate permeability distribution beneath the island.

Water quality

The groundwater is classified as a sodium chloride water whose salt is derived mainly from oceanic salt spray dissolved in rainfall. Water quality is suitable for domestic use in most cases but is above the required salinity limits (< 1000 mg/l TDS) in the northwest plateau, Kingston lowland, and other coastal areas. Groundwater generally falls within recommended quality limits for livestock use (<8000 mg/l TDS) and hardness (<500 mg/l $CaCO_3$). Most groundwaters are suitable for irrigation in terms of low salinity, sodium adsorption ratios (SAR), bicarbonate, and boron, but only a few bores sustain sufficiently high yields for considerable time periods for irrigation schemes to be widely practised. Groundwater pollution due to seawater contamination, refuse disposal, livestock, and septic tank waste is not a widespread problem.

Groundwater consumption

At present groundwater supplies on the island are provided almost exclusively from the weathered zone capping the southern apron, which is the area where most people live and where there is the greatest concentration of bores and wells. Total groundwater consumption is estimated at 1.0 $\times$ 10^5 m^3/year which accounts for approximately 40 percent of total water use (2.4 $\times$ 10^5 m^3/year). However, a large proportion of groundwater extracted passes back to the ground as sanitary waste through the septic tank system that operates on the island. Hotels and accommodations catering for tourists have a large groundwater consumption in excess of 4.5 $\times$ 10^3 m^3/year. From water balance calculations the total volume of groundwater recharge is 6.3 $\times$ 10^6 m^3/year (14 per cent of average annual rainfall) which suggests that enough groundwater exists to satisfy normal water demands over the next few years provided that appropriate water resources management techniques are applied.

PHOTOGEOLOGY AND REMOTE SENSING, BY C. MAFFI & C. J. SIMPSON

STAFF: C. Maffi; C. J. Simpson; P. C. Brugman part-time from November to March; G. F. Sparksman part-time from April to June.

BMR mapping projects

Assistance with photo-interpretation was given in the following projects: Musa River Damsite, Papua New Guinea (interpretation of areas of structural weakness and of potential landslides in the vicinity of the proposed damsite); Norfolk Island (annotation of fracture traces on colour and black and white photos to detect relationships between fracturing and groundwater occurrences); Dairy Flat Engineering Survey, A.C.T. (detailed study of all available airphotos taken from 1944 to 1973 to determine the recent depositional history of the Dairy Flat river sediments, as an aid to differentiating sand and gravel deposits on seismic and resistivity records).

Remote sensing

Landsat-1 (formerly ERTS-1) images were used to detect major structural lineaments in the Officer and Wiso Basins. Both are areas of thick soil and sand cover. Straight and circular features were detected; some of the straight lineaments correlate with known structural features.

An experiment was successfully carried out on the possibility of combining parts of two Landsat scenes in the multispectral viewer, with the purpose of better centering an area of interest. The multispectral viewer was used by BMR staff and representatives from two private companies and three government departments. Good reproduction of Landsat scenes in black-and-white or false-colour can easily be made by photographing the screen of the viewer.

The group took part in an experiment organised by CSIRO Mineral Physics Laboratory, involving the comparison of various interpretations of a Landsat scene by different people, to assess the system reliability in providing geological structural data. Analysis of the interpretations was in progress at the end of the period.

The group was routinely involved in updating Landsat catalogues and in ordering images from NASA.

The BMR proposal for participation in the geological evaluation of *Landsat-2* imagery was not accepted by NASA.

The BMR involvement in the *Skylab/EREP (Earth Resources Experimental Package)* experiment was carried out to determine the usefulness to geological mapping of space photographs taken with high-quality cameras and returned to Earth for processing and printing (as distinct from Landsat images which are produced by scanning the Earth surface, tape-recording, digitizing, and transmitting the information to Earth, and finally processing it to obtain a pictorial display of the original data). The cameras used were a set of six 15-cm focal length cameras (S190A), and a 45-cm camera (S190B); the resulting photographs had scales of 1:2 860 000 and 1:948 000 respectively. Positive transparencies and paper prints enlarged to 1:1 000 000 and 1:500 000 respectively were used for the study. The cloud-free coverage of Australia is limited to one area in the Alice Springs region and a 160-km-wide strip from the Hume Reservoir through the Snowy Mountains to the coast near Bega. The photo-interpretation was commenced in November 1974; a progress report was sent to NASA in February 1975 and the final report was completed in April.

In the Alice Springs area the study has shown that the S190B colour photographs can be used to prepare reliable 1:500 000 geological maps when controlled with a limited number of selected field traverses. Some rock types (e.g. travertine) can be more readily mapped on Skylab colour photographs than on conventional RC9 photographs.

In the Snowy Mountains area the study has shown that linear features interpreted from S190A photographs with 3X magnification are related to Mesozoic and Cainozoic structural trends, and to lithology; those interpreted from the same photographs without magnification are related to Palaeozoic structural trends. The linear features interpreted from S190B colour photographs do not seem to be related to geology; they were digitized and will be statistically analysed by means of a computer program obtained from CSIRO

Mineral Physics Laboratory. The nature of several circular features visible on all types of images was investigated by use of conventional airphotos and geological maps; most of them are connected with the presence of intrusive or volcanic features, but one is a watercourse displaced by a landslide. In conclusion, Skylab photographs in this area provided structural information (mainly faults and lineaments), which can be used to update geological maps, but very little lithological information.

The general conclusion of the BMR investigation is that the small-scale aerial photography (1:1 000 000 and smaller) would be a valuable aid in geological mapping, particularly in the arid regions of Australia.

The results of the *Mount Isa SLAR study* (reported in the 1974-75 annual report) were distributed as BMR Record 1974/150.

A report titled '*Aerial thermal infrared imaging over coal measures, Hail Creek, Qld 1971*' was prepared as a BMR Record. Editing is in progress.

An area between Mary Kathleen and Cloncurry was selected for the evaluation of the geological usefulness of *multiband aerial photography* flown by CSIRO in 1972. The photographs were received at the end of the period; the study is programmed for 1976.

Other activities

Indexing of the photographs and preparation of flight diagrams for all *BMR experimental 70-mm photography* were completed. The films and copies of the flight diagrams were delivered to the Division of National Mapping for storage in their Melbourne airphoto library.

Detailed photo-interpretation was carried out of areas of the Amadeus Basin selected for *IGC field excursions*. A brief field visit was made to check the interpretation.

In preparation for possible BMR involvement in the geological mapping of *Irian Jaya*, a complete catalogue and pictorial index of Landsat coverage was prepared.

Training was given to twelve geologists and four technical officers and draftsmen in basic photogeological interpretation techniques. Four lectures were delivered to BMR personnel, to visiting study groups, and to students at ANU Geology Department. Preparation is in progress for a BMR in-house training course in photogeology and for participation in a UN/FAO Seminar on Remote Sensing applications, Jakarta, both to be held in November 1975.

Exhibitions of remote sensing material were prepared for three oversea and seven local visiting groups and for delegates to the International Training Course in Mineral Exploration.

Australian Committee for ERTS (ACERTS), by W. J. Perry

The Branch continued to provide the Secretariat for the inter-departmental committee, ACERTS, until February, when the Department of Science took over, Mr K. Fuller becoming Chairman in place of Mr B. P. Lambert, Director of the Division of National Mapping. Mr Lambert remained Principal Investigator for the Skylab and Landsat-2 (formerly ERTS-2) programs. At this time the responsibilities with respect to NASA projects remaining with BMR were the compilation of a consolidated Landsat-1 (ERTS-1) report from the 39 individual investigator reports, administration of the Skylab program and compilation of the Skylab final report from the five individual investigator reports.

The consolidated Landsat-1 report was sent to NASA in April, and notification of approval received the following month. Three areas, namely Mount Isa, Alice Springs, and Canberra, were studied at BMR, and it was concluded that Landsat-1 imagery is a useful aid to small-scale regional geological mapping. It was also recommended that with future satellites NASA try to provide higher-quality early-generation imagery with more extensive stereoscopic and low-sun-angle coverage.

In July the draft final Skylab report was sent to NASA for comment, but no reply had been received by the end of the period. The results of the BMR study are given in the previous section.

Only a limited amount of Skylab photography of Australia is available, but the work done suggests that small-scale aerial photography (1:100 000 and smaller) would be a valuable aid in natural resources mapping.

The five-man multidisciplinary scientific team sent by the Government to Canada, the United States, and Brazil in October 1974 to investigate applications of Landsat-1 and other remote sensing data in the earth resources field, returned to Australia in mid-November. The geological representative was W. J. Perry. The purpose of the visit was to obtain information to help the Government to decide what level of involvement may be appropriate in future earth resources satellite programs. The team report was submitted to the Department of Science and Consumer Affairs in January, and the ACERTS committee at a meeting in February appointed a working group to prepare a covering paper to accompany the team report. By mid-September both documents had been distributed to the Australian Agricultural and Environment Councils and to members of ACERTS.

At the BMR Symposium in April, W. J. Perry presented a lecture on applications of Landsat-1 and other remote sensing data in the geological and mineral resources fields, and toward the end of the period the lecture was repeated by invitation at the Universities of Wollongong and New South Wales.

MARINE GEOLOGY AND COASTAL STUDIES

HEAVY MINERAL SANDS, BY H. A. JONES

A shallow seismic survey was carried out in November and December 1974 over the New South Wales continental shelf from Newcastle to the Queensland border; the objectives were to determine the thickness and structure of the superficial sediments. Maps at 1:150 000 scale showing water depth and depth of bedrock have been compiled for this region and interpretation of the seismic profiles (Fig. S9) is continuing. Little evidence of depositional structures in the sediment cover has been seen. Study of the heavy mineral content of surface grab samples on the inner continental shelf suggests that relatively higher concentrations are present directly offshore from the known deposits on land; this indicates that there has not been a general northward migration of the superficial sand body. Synthesis of all available data to plan a drilling program is in progress.

MARINE MINERALS, BY P. J. COOK

A review paper 'Minerals from the sea' was prepared for a symposium of the Royal Society of Tasmania on ocean resources and also for the Honiara meeting of the fourth session of the Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas. The review considers the distribution and potential of two basic types of deposits—superficial deposits and bedrock deposits (Fig. S10). Much of the presently available technology could be used for exploiting these deposits, particularly those on or under the shelf. Although most of the known offshore deposits will not be extracted in the short term, they nevertheless constitute important resources for the future.

EAST TASMANIA SHELF, BY P. J. DAVIES

Interpretation of seismic data collected off Tasmania in 1973 was carried out. About 650 km of profiles between latitude 40°50′S and 43°10′S have been examined (Fig. S11).

Acoustic basement is represented by an eastward-sloping bedrock surface of Devonian, Permian, and Jurassic sedimentary and igneous rocks. It is an unconformity which is traceable westwards towards the cliffs forming the present-day coast (Fig. S12). Basement highs occur on the outer shelf to the east of Cape Naturaliste and the Freycinet Peninsula; the thickest sediment sequence occurs to the southeast of Great Oyster Bay. At the outer edge of the shelf the sedimentary sequence exceeds 400 m in thickness in most areas. The highly irregular basement profile to the east of Cape Naturaliste suggests an offshore extension of the onshore Devonian granites. The shelf break is easily identifiable and ranges in water depth between 120 and 150 m. Palaeo-shelf breaks are recognizable in the subsurface. These may owe their origin to faulting or erosion during lower sea levels. The depth variation of the oldest recognizable surface broadly parallels that of the present-day shelf break, both of which conform with delineated basement highs and lows.

CENTRAL AND SOUTHERN N.S.W. SHELF, BY P. J. DAVIES

An appraisal of sedimentary and geochemical processes operative on the continental shelf of southeast Australia has been completed. Granulometric analysis shows that four different types of sediment occur in the depth zones 0-15 m, 15-60 m, 60-120 m, and 120 m to the shelf break. Between 0 and 15 m the sediments are dominantly quartz sands in equilibrium with the modern depositional environment. Between 15 and 60 m quartz sands again dominate but textural relations suggest a relict origin. In the mid-shelf zone between 60 and 120 m, mud and fine quartz/carbonate sand predominate; the origin of these sediments is still in doubt. They

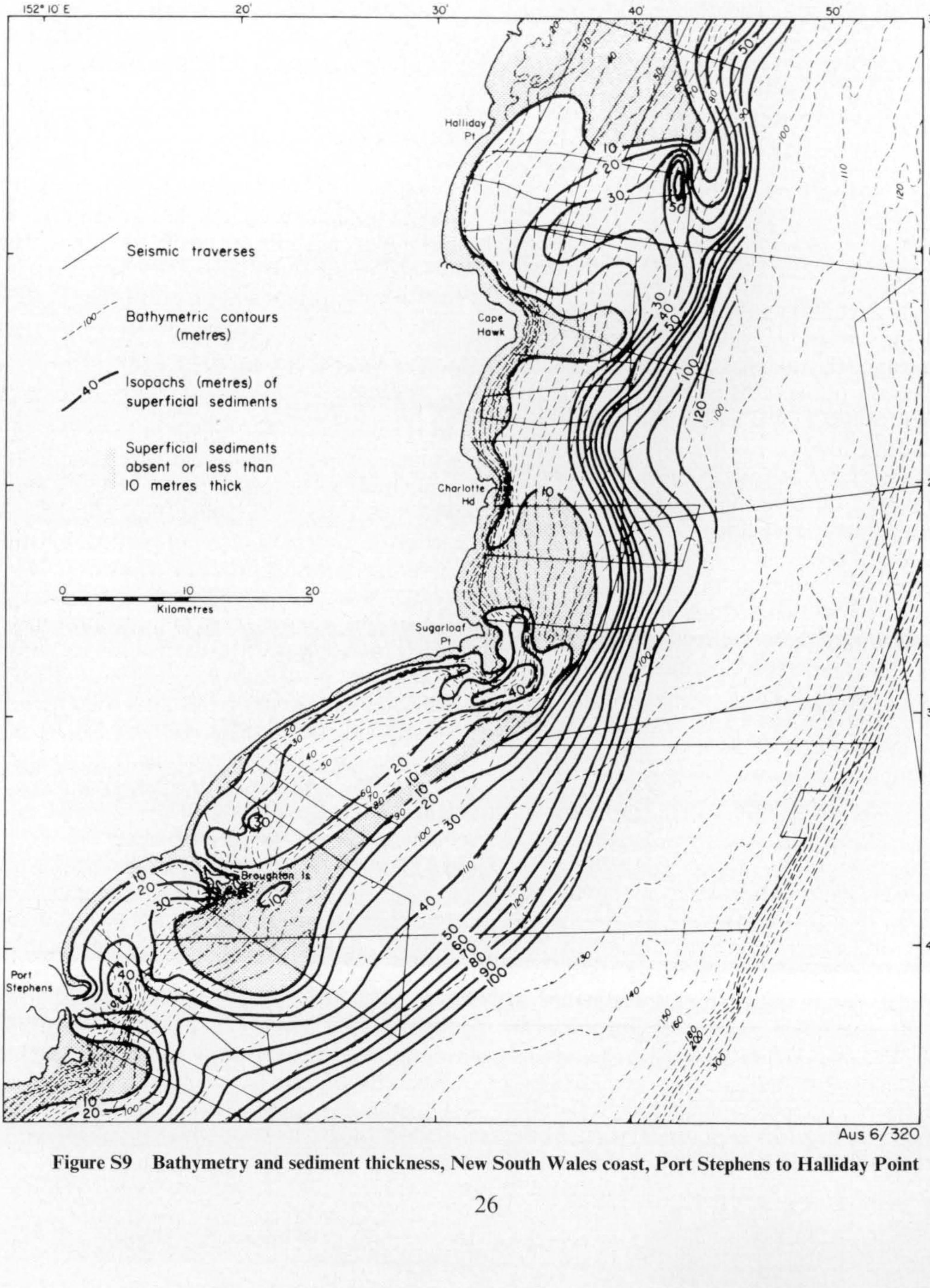

Figure S9 Bathymetry and sediment thickness, New South Wales coast, Port Stephens to Halliday Point

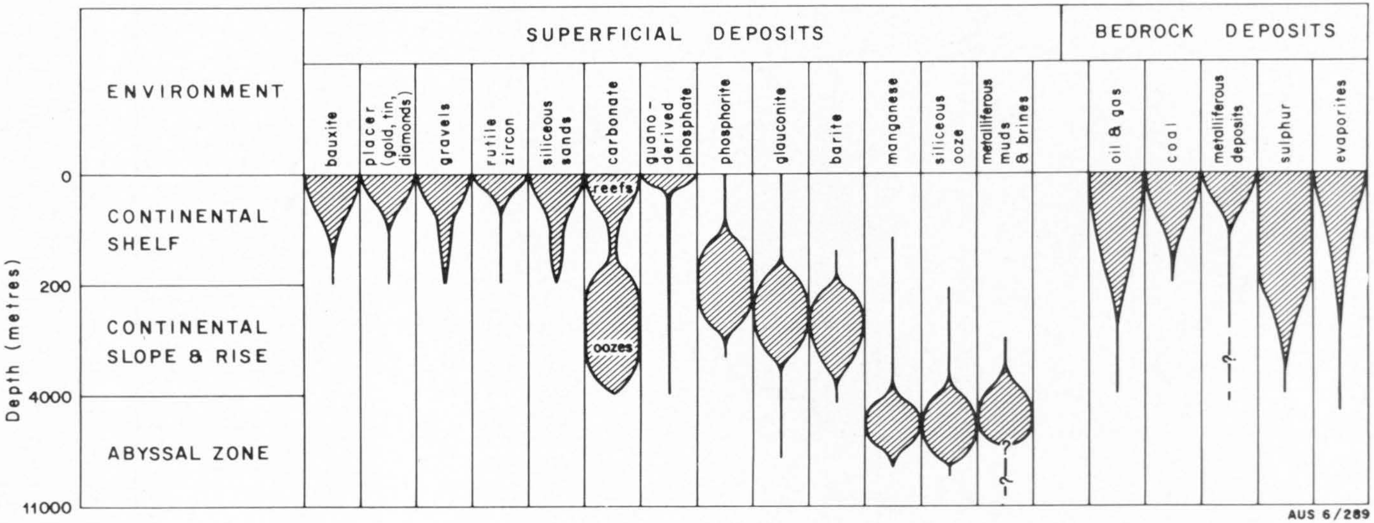

Figure S10 Schematic representation of the distribution of marine mineral resources

may be partly or wholly relict. The outer shelf zone deeper than 120 m is covered by iron-stained carbonate sands which are probably relict. Each sediment group is characterized by a distinct geochemical imprint.

R-mode factor analysis suggests that five major causes control the geochemical distribution; these are mineralogy, physiochemistry, biochemistry, past and present depositional environments, and diagenetic en-

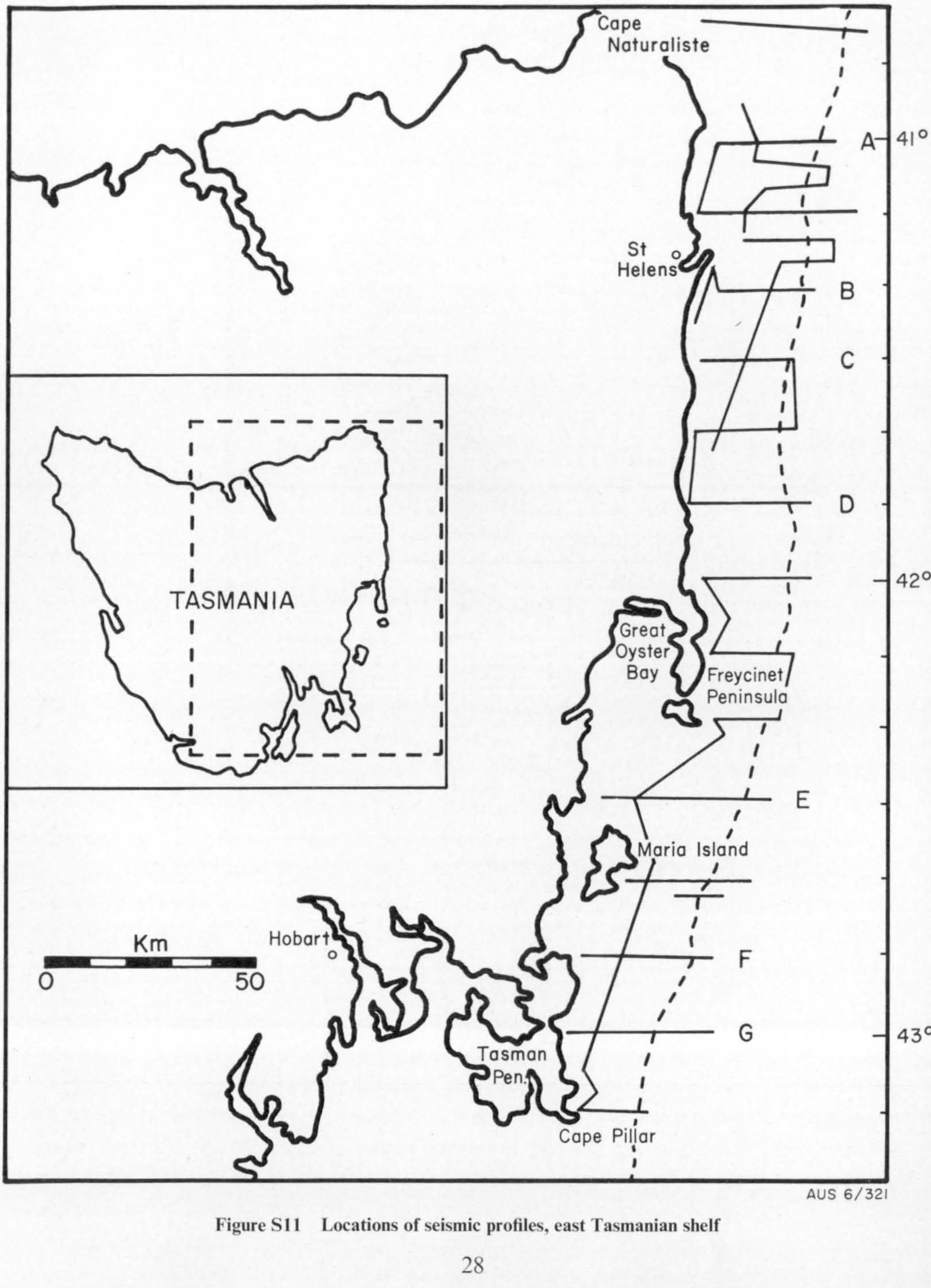

Figure S11 Locations of seismic profiles, east Tasmanian shelf

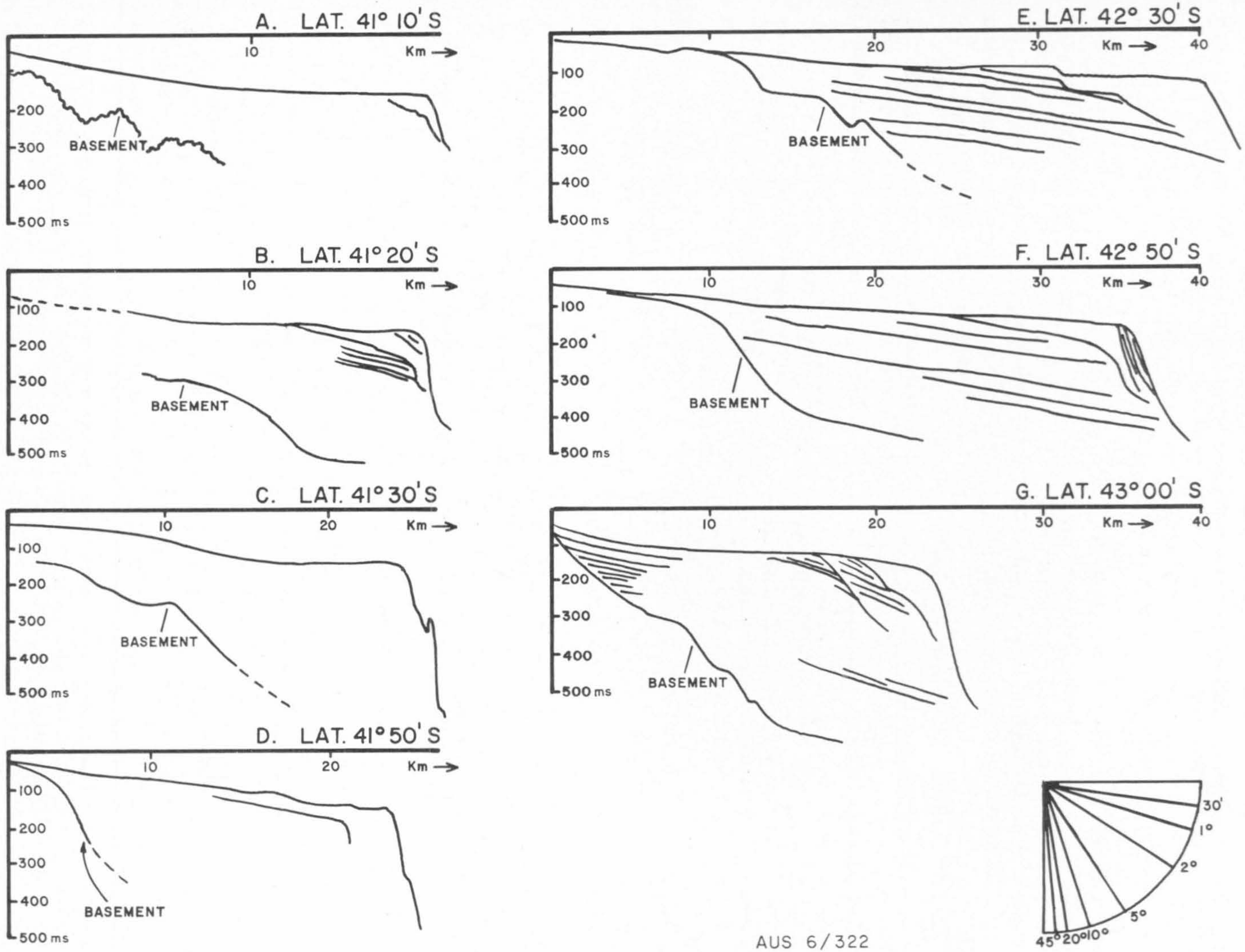

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Figure S12 Interpretation of seismic profiles, east Tasmania shelf (Figure S11 shows location of profiles) vironment. The distribution of pollutants may extend far outside the nearshore zone. Arsenic is most concentrated on the outer shelf. Conversely, some pollutants like zinc concentrate in the nearshore zone close to the pollutant source. The concentration of metals in sediments is ultimately a function of both the reactivity of the metals entering the environment and the rate of diluent sedimentation. Continental shelves, exhibiting relict features, adjacent to major industrial/urban centres provide excellent opportunities for studying metal transport and accumulation.

CORAL REEF STUDIES, BY P. J. DAVIES

Davies was invited to prepare a paper for the Australian Conservation Foundation on the Formation of the Great Barrier Reef. Two aspects were stressed—the early Tertiary history and the post-Pleistocene development. The Barrier Reef has grown on the Queensland continental shelf, a feature which came into existence 50 to 60 million years ago. Coral reefs began to grow in the lower middle Miocene. The present-day reefs owe their shape and size to the depth and shape of the Pleistocene karst surface on which they have grown; such reefs are only 8000 to 9000 years old.

A paper has been prepared describing the second recorded occurrence of ooids from the Great Barrier Reef. The ooids, discovered at Lizard Island, are composed of radial fibrous aragonite. The absence of diagenetic alteration and the open porous nature of the fibous layers suggest a recent age for their formation. Similar structures precipitated in the laboratory formed under conditions of non-agitation from both hypersaline and standard seawater solutions.

DEEP-SEA DRILLING

Indian Ocean sediments, by P. J. Cook

Relevant deep-sea drilling information was compiled in order to establish the pattern of Mesozoic-Cainozoic sedimentation in the eastern Indian Ocean, as a contribution to a special publication of the Geological Society of America. The 19 sites drilled in the eastern Indian Ocean indicate that there are three main sedimentary units: a lower acoustically transparent pelagic clay, a layered calcareous ooze, and an upper acoustically transparent siliceous ooze. The $CaCO_3$ content of the sediments varies markedly, though the general trend is of poorly calcareous Mesozoic sediments and richly calcareous Cainozoic sediments. Overall, sedimentation was discontinuous as there are numerous unconformities within the sequence. These gaps in the sedimentary record, and also the rate and type of sedimentation, are related to the pattern of continental dispersal in the Mesozoic-Cainozoic (Fig. S13). The northward movement of India was important as it opened a seaway to the west of Australia and enabled cool erosive currents to enter the region, thus modifying the sediment pattern and producing major hiatuses. Subsequently, the influx of Antarctic bottom water and later the development of the Circum-Antarctic Current were important in influencing sedimentation in the eastern Indian Ocean.

In addition to work on the eastern Indian Ocean, Cook was also involved with the work of the DSDP committee of the Geological Society of Australia.

Timor Trough, by T. H. Donnelly (Baas Becking Laboratory)

A geochemical investigation of several drill cores from various sites in the eastern Indian Ocean by P. J. Cook revealed anomalously high titratable alkalinity and low sulphate at Site 262. The sediments examined at Site 262 range from Pleistocene to Pliocene, and are composed predominantly of calcite and clay minerals, with various amounts of aragonite, dolomite, quartz, and feldspar, and traces of pyrite and zeolites. There is a marked increase in the proportion of calcareous components with depth. The geochemical anomalies suggested that bacterial sulphate reduction had occurred at some stage during formation and/or diagenesis of the sediment pile.

To test this hypothesis samples from Site 262 were examined. The titratable alkalinity decreases with depth, and this is accompanied by an almost parallel trend in the delta-34s values of pyrite, which decrease from —15 to —28 per thousand. This isotopic trend is similar to that expected during bacterial sulphate reduction in a closed or partly closed system. The pyrite is largely framboidal, a form which is commonly associated with biogenic pyrite.

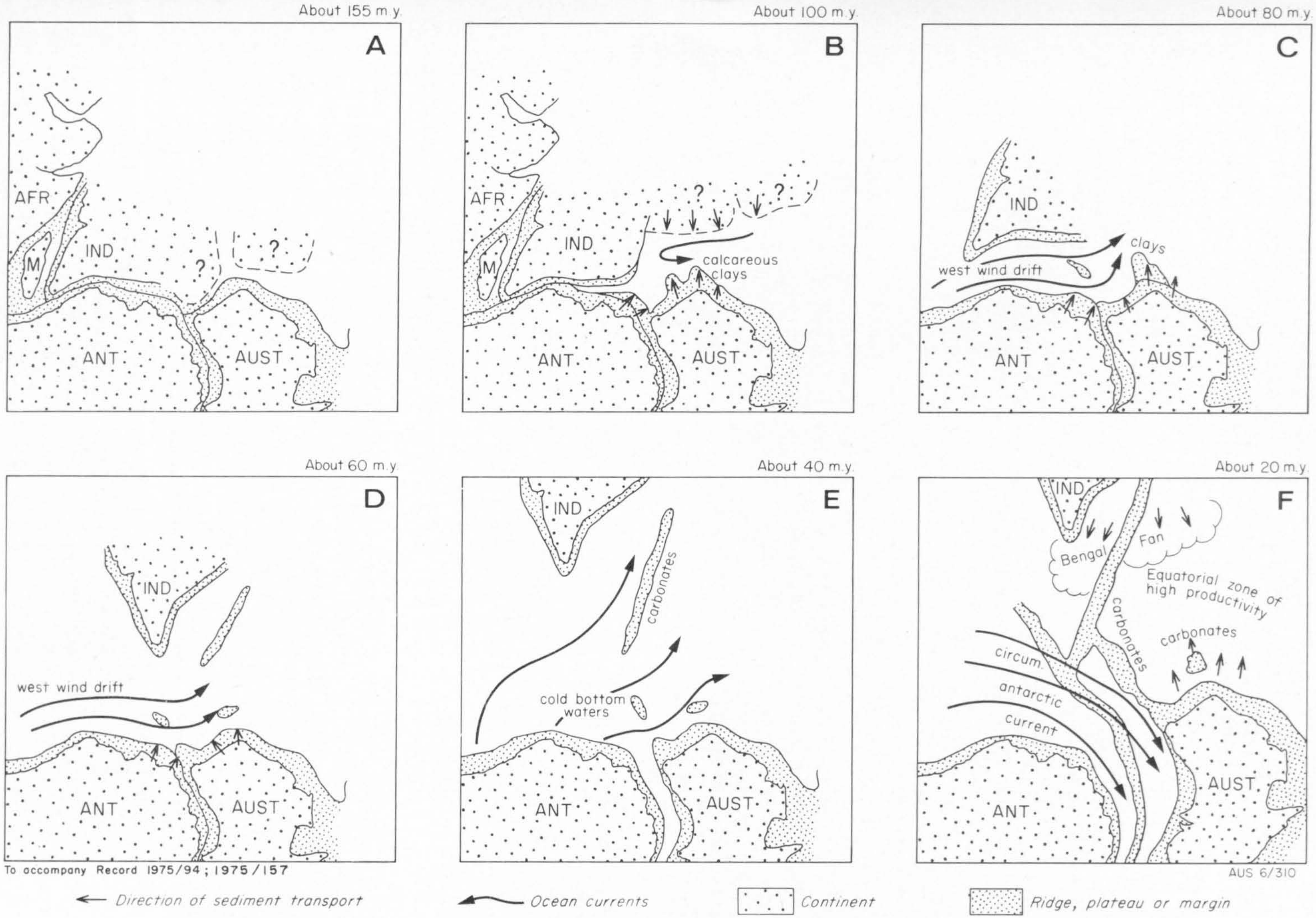


Figure S13 Pattern of continental dispersal during late Mesozoic-Cenozoic, and influence of this movement on ocean currents and sedimentation

Antarctica, by E. M. Truswell (formerly Kemp)

Results from Leg 28 drilling by the *Glomar Challenger* were published during 1975 in the Initial Reports of the Deep Sea Drilling Project, Volume 28. Specialist contributions to this volume included an article on the palynology of drill-sites close to Antarctica (Ch. 16) and one on the diachronism of the silica/carbonate facies boundary in the Southern Ocean (Ch. 33).

A review of microfloras recovered from drill-sites in the Ross Sea has also been prepared and submitted for publication jointly with P. J. Barrett, Victoria University of Wellington. Palynological analyses at site 270 suggest that vegetation in the Ross Sea area persisted into the late Oligocene, at which time it probably coexisted with the earliest glaciers. Evidence from sedimentation rates in the sequence suggests that these early glaciers were of wet-base, temperate type, so limited vegetation cover is not incompatible with such restricted ice development.

Ninetyeast Ridge, Indian Ocean, by E. M. Truswell

Diverse pollen assemblages occur in basal sediments at Sites 214 and 254 on the Ninetyeast Ridge crest, and reflect the vegetation of islands which were once emergent along the line of the ridge. Microfloras from the sites have much in common with Australian Early Tertiary pollen assemblages, a situation which is readily explained in reconstructions of the Indian Ocean which show the island sites much closer to the Australian landmass at the time of their emergence than they are now.

A preliminary account of the assemblages at Site 254 appeared in Volume 26 of the Initial Reports series. Papers completed during 1975 (in conjunction with W. K. Harris, of the S.A. Department of Mines) include a general discussion of the phytogeographic problems associated with establishment of vegetation on these island sites, and descriptive taxonomic studies of the pollen, spores, and fungal remains.

COASTAL STUDIES, BY PETER J. COOK

Estuary studies

Writing-up of the Broad Sound study continued during the year. The manuscript of the first Bulletin by Cook and Mayo dealing with the sedimentology and Holocene history of Broad Sound was completed early in the year. A second Bulletin, plus a short paper dealing with the mathematical procedures used in the handling of Broad Sound data, was prepared by Mayo. Using Q-mode factor analysis it was possible to classify the Broad Sound estuarine samples into separate sedimentary units each representing a distinct set of geological processes. A third Bulletin concerned with the geochemistry of Broad Sound is currently being written by Cook and Mayo.

The manuscript of the Bulletin on the Genoa River estuary by Reinson is being edited for publication.

Southeast South Australia

The Bureau of Mineral Resources, in conjunction with the South Australia Department of Mines and Flinders University, commenced a study of the Quaternary sediments of the southeast corner of South Australia during the year. This part of South Australia is characterized by a series of elongate calcareous sand ridges which are believed to have formed during times of high sea level. In order to establish the sequence with greater precision, and in the hope of finding datable calcareous material which would in turn assist in establishing a Quaternary sea-level curve, a series of holes was drilled across the coastal plain (Fig. S14). The main line of section was between Robe and Naracoorte, where a total of 30 holes was drilled; in addition, a number of holes were drilled off the line of section to establish the true dip of the Gambier surface. A second series of holes was drilled through the older ridge sequence in the Keith-Bordertown area.

The information obtained to date is summarised in Figure S15. The general picture is of gently seaward-dipping Gambier Limestone overlain by up to 50 m of probably Quaternary sediments. Drilling revealed that the dunal calcarenites and interdunal calcilutites and clays are underlain in many areas by a shelly sand of probable shallow-marine origin. There appear to be four distinct dunal

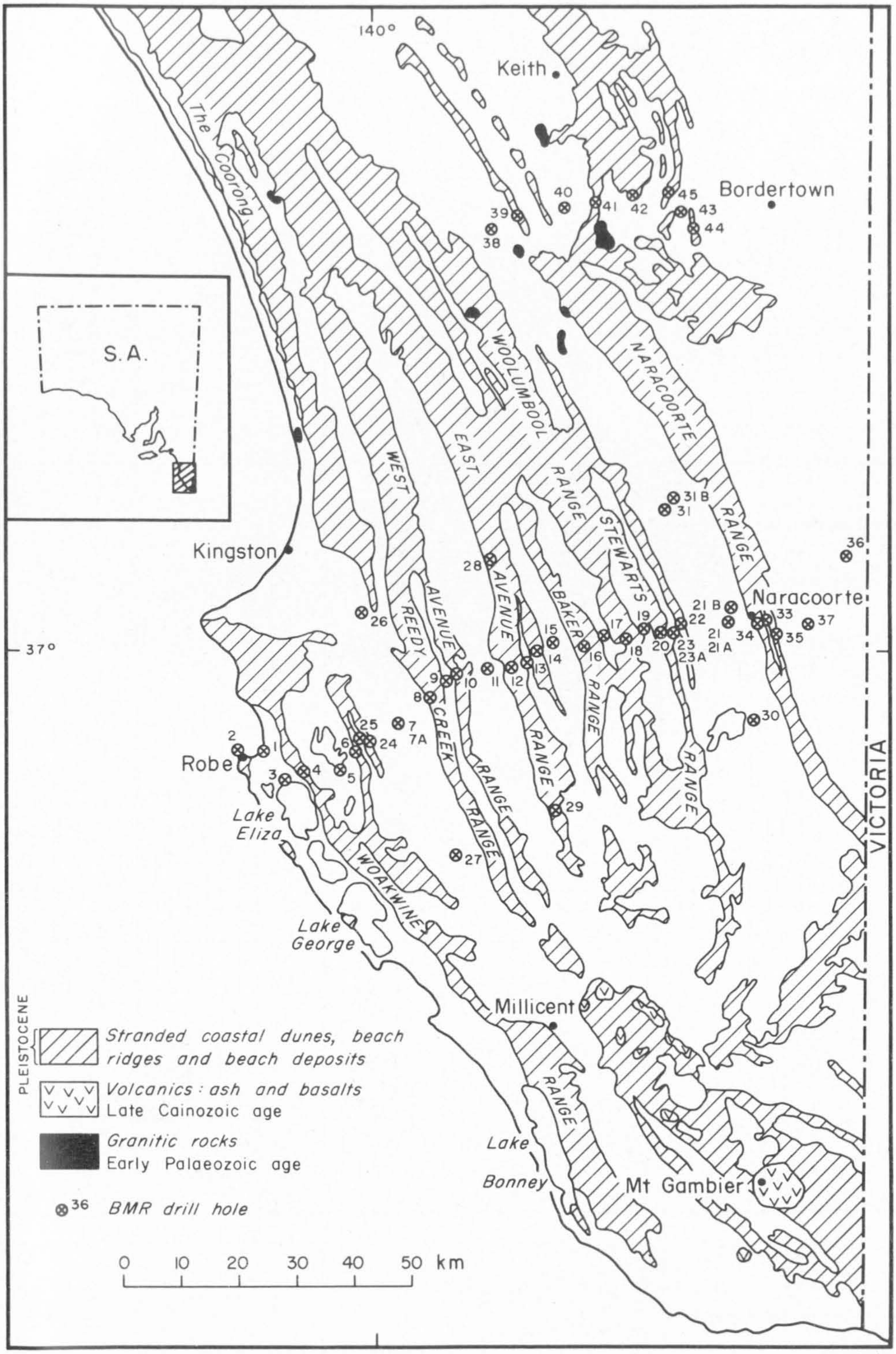


Figure S14 Locations of drill holes, Quaternary sediment study, southeast South Australia

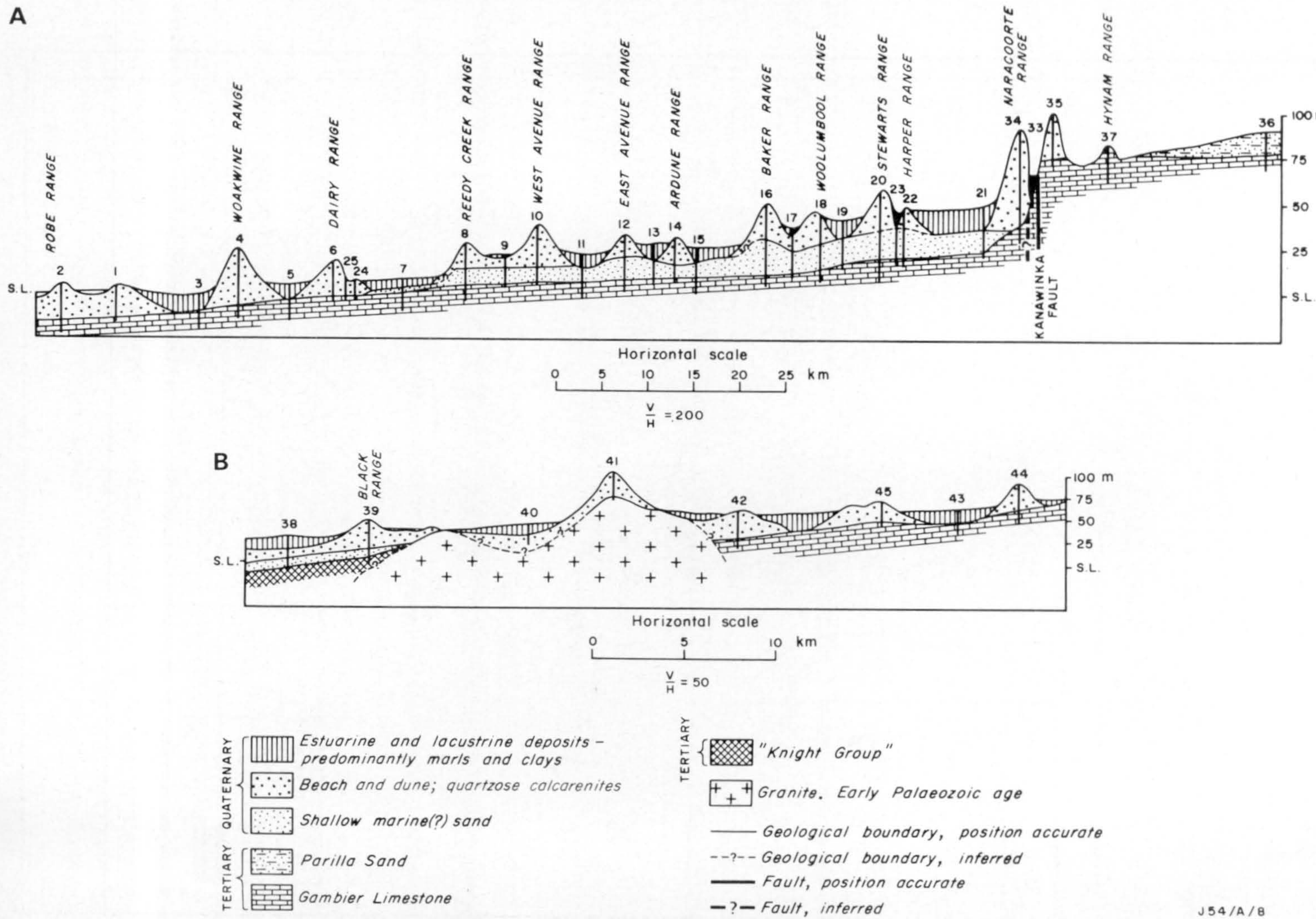


Figure S15 Sections through beach-ridge sequence of southeast South Australia (numbers refer to drill holes shown in Figure S14) groupings on the basis of elevation. These are (i) Robe Dune to the base of the Reedy Creek Dune, (ii) Reedy Creek Dune to the base of the Baker Range, (iii) Baker Range to the base of the West Naracoorte Dune, (iv) West Naracoorte Dune, inland. The changes in elevation of these four sets of dunes and interdunes are also reflected in the thickness of the underlying marine sand. It is suspected that the dune sequence may have been deposited in four discrete episodes separated by erosive phases. This episodic hypothesis differs somewhat from the regularity of deposition proposed by Sprigg.

A program to determine the nature, distribution, and provenance of heavy minerals in the region is also under way. To date it appears that heavy minerals are not abundant, the average concentration of total heavy minerals being less than 0.5 per cent. The assemblage is composed of opaques, tourmaline, zircon, epidote, hornblende, and minor to trace rutile, andalusite, kyanite, sillimanite, and garnet. Fairly extensive sampling of likely source areas was undertaken and ultimately it is hoped to establish the source area for the heavy minerals. This may in turn assist exploration companies in locating heavy-mineral deposits in the area.

QUATERNARY COASTAL AND HEAVY-MINERAL DEPOSITS, BY J. E. GARDINER

A bibliographic study of Quaternary coastal deposits and heavy minerals commenced in March 1974 and continued during 1975 with the twofold aim of producing (i) an ADP-based bibliography of relevant published and unpublished documents, and (ii) 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.

So far, 400 published and unpublished references have been collected as a result of visits to the Geological Surveys of Queensland, New South Wales, Victoria, Tasmania, and South Australia and from bibliographies supplied by the Geological Survey of Western Australia and Dr. B. Thom of the Australian National University. The bibliography is based on the SURFAUST system, which sorts the references on the basis of keywords, author's name, year of publication, and 1:1 000 000 and 1:250 000 Sheet areas. Twenty-nine keywords have been used covering topics such as physiographic environment and the type of heavy mineral mined.

During 1975 the synthesis of information on Quaternary coastal deposits and heavy mineral sands along the east coast of Australia was completed. It was concluded that: (1) Quaternary coastal history is important in explaining the location of many of the large heavy-mineral concentrations, the largest deposits being found in areas with the longest history of sedimentation and where there are inner and outer barriers and/or transgressive dunes; (2) the concentration of heavy minerals is aided by the erosion of earlier inner barrier and dune systems and their subsequent redeposition in outer barriers; (3) the large heavy-mineral accumulations between Woy Woy and Brisbane are bordered by a high-wave-energy coast with a small tidal range and a narrow shelf; (4) there is no clear indication of the provenance of the heavy-mineral suite, along the coast; and (5) that the part of the coast protected by the Great Barrier Reef seems devoid of large heavy-mineral accumulations. A series of maps portraying features affecting heavy-mineral sand accumulation and the distribution, size, and mineralogy of the heavy-mineral deposits was completed with an accompanying Record (BMR Record 1975/92).

The collection of data concerning heavy-mineral deposits along the southern coasts of Australia (excluding Western Australia) was also completed during 1975. Information came mainly from the files of the Victoria, Tasmania, and South Australia Geological Surveys and a search of relevant literature. Currently a Record and accompanying maps are being prepared. This study has shown marked differences between eastern and southern heavy-mineral deposits, those on the southern coasts being smaller and associated with recent coastal landforms (6000 years B.P.)

The plans for 1976 are (i) to complete the collection of data from Western Australia and the Northern Territory, and (ii) to complete the bibliography of Quaternary coastal and heavy-mineral deposits.

URANIUM-SERIES DATING, BY J. F. MARSHALL

This dating technique is based on the observation that carbonates precipitating in nature show an initial disequilibrium in U^{238} series, i.e. the amount of Th^{230} initially present in the carbonate is negligible in comparison to that subsequently generated by the radioactive decay of uranium. Therefore, the growth of Th^{230} toward a state of radioactive equilibrium with its parent uranium can be used as a measure of the age, providing the carbonate has remained a closed system since its formation. There is a 15-percent excess of U^{234} over U^{238} in the present-day ocean, and this disequilibrium has to be taken into account when determining the age. However, the U^{234}/U^{238} disequilibrium can itself be used as a dating technique. Absolute age determinations using the Th^{230}/U^{234} disequilibrium method can be made for marine carbonates up to 250 000 years old, while the U^{234}/U^{238} disequilibrium method has a limit of about one million years. Not all marine carbonates are amenable to uranium-series dating: unrecrystallized reef corals and ooids tend to give the most reliable results. Coral reefs form an ideal marker for former sea-level stands, and the ages of the corals can provide a chronology for late Quaternary eustatic sea-level changes, and neotectonic uplift rates.

Th^{230}/U^{234} ages of corals have been determined from Papua New Guinea, the Great Barrier Reef, the east coast of Australia, and the Loyalty Islands. Corals from uplifted reefs on the Huon Peninsula, Papua New Guinea were dated to check the reliability of the techniques and counting equipment used by the BMR laboratory. These corals had previously been dated by the Th^{230}/U^{234} method (Bloom et. al., *Quaternary Res.*, 1974, 4, 185-205). Agreement between both sets of data was usually within the error limits of the original age determinations, thus confirming the reliability of the techniques used in the present study.

Coral samples from drill holes put down on the fringing reef of Hayman Island have been provided for dating by James Cook University. A coral from a depth interval of -16.8 to -18.3 m gave an age of 8300 $\pm$500 years B.P. A marked solution unconformity is present below this depth, and corals below this solution unconformity are predominantly recrystallized, and are therefore unsuitable for uranium-series dating. Recently, however, two aragonitic corals were found at depths of about -22 and -30 m. These corals should provide valuable information on the times of reef growth in the Great Barrier Reef province.

Th^{230}/U^{234} ages of corals recovered from the inner barrier beach system at two sites, one near Newcastle and the other near Evans Head, have shown that the inner barrier was formed during the last interglacial period. Work on this project is continuing, and more corals are to be dated from the Evans Head site and a newly discovered locality in Moreton Bay.

Th^{230}/U^{234} ages of corals from the Loyalty Islands have made it possible to determine the varying uplift rates of each island over the past 200 000 years.

OVERSEAS STUDIES, BY D. JONGSMA

From October 1971 until March 1975 D. Jongsma worked at the Department of Geodesy and Geophysics, Cambridge University, U.K., supported by an Australian Government Postgraduate Scholarship. The work was within the University marine group which studied the geophysics and geology of the eastern Mediterranean Sea. He participated in two cruises on the British vessel R.R.S. *Shackleton* and one on the German ship F.S. *Meteor*. For three months he worked in Hanover, West Germany, at the Bundesanstalt fur Bodenforschung on seismic profiling results from the southern Aegean Sea. He completed his thesis entitled ‘A marine geophysical study of the Hellenic Arc’ in January 1975 and received a Ph.D. on 22 March. Two publications resulted from this work, and the results were also presented at the 1st European Geophysical Conference in Zurich and a C.I.E.S.S.M.M. Meeting in Monaco.

EVAPORITE STUDY, by A. T. Wells & A. J. Stewart

The objectives of the evaporite study are to investigate some new surface evaporites by shallow drilling and to review all known Australian occurrences. No comprehensive field studies were made in 1975 but reporting on previous work in Australia-wide occurrences and drilling in the Amadeus and Officer Basins was completed in the Records series. These will be revised for publication.

Amadeus Basin

Record 1974/145, 'Petrographic and geochemical study of the Ringwood evaporite deposit' by A. J. Stewart, was issued; Report 186 (same title) is with the editors. A lecture entitled 'The Ringwood evaporite deposit—a classical barred-basin, marine evaporite in the Proterozoic of the Amadeus Basin' was delivered to the Specialist Group in Sedimentology of the Geological Society of Australia at the First Australian Geological Convention, Adelaide, May, 1975. The Ringwood core was sampled for source-rock analysis by D. McKirdy (Petroleum Technology Section, Mineral Resources Branch).

The evaporite deposits at Ringwood, at Titra Well northeast of Gaylad Syncline, and at Santa Teresa were visited briefly during the I.G.C. excursion survey. All the deposits with the exception of those at Titra Well, were considered to be Precambrian, but investigation of the Santa Teresa deposit showed that it is most likely Tertiary and probably part of a lacustrine sequence. The Titra Well deposits occur in Cainozoic aeolian sands; the chemistry and petrography of these deposits is being investigated.

Australia-wide evaporite review

The report on the occurrence of Australia-wide evaporite deposits is being collated for issue in the Records series. A continuing review of data on Australian evaporites was maintained. Further discoveries of evaporite deposition have been made recently in northern Australia. Intersections of anhydrite and gypsum occur in a drill-hole in the Wiso Basin; the formation is tentatively assigned to the early Middle Cambrian Montejinni Limestone. Halite casts have previously been reported in this formation in the Wave Hill area. Bedded anhydrite and gypsum replaced by coarse siderite and dolomite and silica up to 30 m thick has recently been discovered in sediments about 1550 m.y. old in the McArthur Basin; only halite pseudomorphs had previously been found in associated formations. Similar replacements of gypsum by siderite and dolomite have recently been found in the Bungle Bungle Dolomite in the East Kimberley Region (K. A. Plumb, pers. comm., 1975).

The current high demand for soda ash by industry suggests that future exploration of Australian evaporites will be directed towards the location of trona-rich deposits.

PALAEONTOLOGICAL STUDIES (Fig. S16)

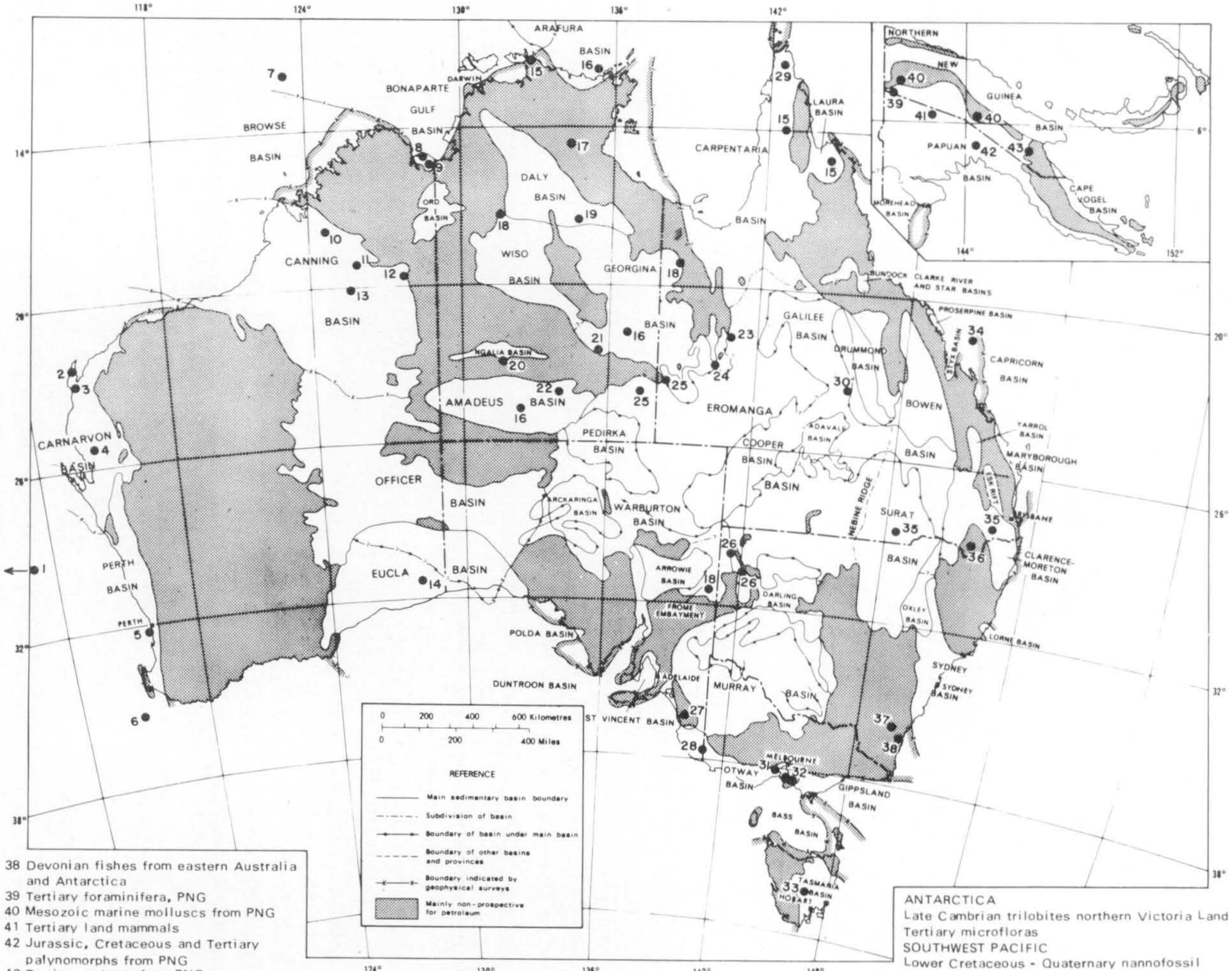
S. Shafik joined BMR on 22 April to study calcareous nannofossils and their application to stratigraphy.

C. G. Adams, of the British Museum (Natural History), London, visited BMR on 3-6 June to further his work on larger foraminifera of the Indo-Pacific region being carried out in collaboration with D. J. Belford.

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.

J. Pojeta Jr, of the United States Geological Survey, completed his year with BMR under the USGS-BMR exchange agreement. He left in July after completing manuscripts on the Cambrian and Ordovician molluscan classes Rostroconchia and Pelecypoda from northern Australia. M. D. Muir, of Imperial College, London, continued her work in collaboration with BMR on Precambrian microfossils. Considerable work has been

1 Eocene nannofossils, Tertiary pollens, Ninetyeast Ridge
2 Oligocene and Miocene larger and planktonic foraminifera
3 Upper Cretaceous-Eocene nannofossil biostratigraphy
4 Palaeozoic conodonts, Carnarvon Basin
5 Paleocene and Middle Eocene nannofossils
6 Eocene nannofossils Naturaliste Plateau
7 Miocene larger 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, Napperby 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 Palynology of the Jurassic- Early Cretaceous "Longsight Sandstone"
26 Cambrian mollusc Stenothecoides (Bancannia Trough)
27 Silicification of modern algae
28 Eocene nannofossil biostratigraphy
29 Upper Mesozoic pollen, spores and microplankton from the northern Carpentaria Basin
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 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

M(P)740

Figure S16 Current palaeontological projects

carried out on the collections during the year. The long-term object is to allow more satisfactory use both by scientists from BMR and by others. This is expected to result in attracting a wider range of material, and to lead to the establishment of a comprehensive national collection.

Following preparation of a submission to the Committee of Enquiry on Museums and National Collections on the future of Australian palaeontological collections, the group has collaborated with the Australian Biological Resources Study Interim Council in a review of the cost of Australian palaeontological collections and palaeontological taxonomic work.

ACTIVITIES

J. M. Dickins

Work in collaboration with field parties in the Canning Basin has continued. This work will allow a better understanding of the stratigraphy and history of the basin and will contribute to a better world Permian time scale. A report on the newly discovered cold-water marine fauna of the Grant Formation was prepared together with R. R. Towner and R. W. A. Crowe for publication in the Journal of the Palaeontological Society of India.

A paper has been prepared for the Irene Crespin Commemorative Volume on the taxonomy of *Mourlonia* and *Ptychomphalina*, two genera of gastropods which are widespread in the Upper Palaeozoic and whose relationship continues to cause confusion.

Work has continued on the Permian fauna of the Warwick area, Queensland and on the Permian climate of Australia and Gondwanaland. Permian climatic fluctuation and zonation is significant in understanding time relations (correlation).

Long-service leave was taken to attend the Charles Lyell Centenary Symposium in Edinburgh and London and the first meeting of the International Subcommission on Permian Stratigraphy in Moscow. This meeting was held in conjunction with the 8th International Congress on Carboniferous Stratigraphy and ecology and was, in fact, a symposium on the world correlation of the Permian. Decisions at the meeting were aimed at improving the accuracy and precision of Permian correlation.

M. Plane

Work continued on fossil mammal faunas from Bullock Creek in the Northern Territory, Riversleigh in Queensland, Lake Ngapakaldi in South Australia, and the Watut Valley of Papua New Guinea.

It was again decided to postpone the field work in the Tirari Desert as the lakes to the east of Lake Eyre and in the Frome Embayment are still wet and unfit for work. A short visit to the area did make it clear that, unless there is again heavy winter rain, it will be possible to take the post-I.G.C. excursion to the area and to continue the work at Lake Palankarinna.

The complete processing of the samples of Titringo Creek Siltstone from near Nerriga, N.S.W. has not produced any fossil mammals. However, in the light of the yields of specimens per ton of matrix processed from comparable operations overseas, further efforts at this potentially most important site may be justified.

Preparation of the Carl Creek Limestone from Queensland has produced a new record of the genus *Neohelos*, and this important fossil contributes much to an understanding of the evolution of this subfamily of diprotodontids and its usefulness in correlation of non-marine and late Tertiary rocks.

During the year considerable time was spent commissioning the new palaeontological Compactus storage at Fyshwick. Much material which has until now been unavailable is now safely housed, catalogued, and available for use.

A paper on the Tertiary occurrence of the thylacine (Tasmanian Wolf) in the highlands of New Guinea was completed.

S. K. Skwarko

S. K. Skwarko completed stratigraphic tables to accompany the 1:1 000 000 geological map of Papua New Guinea, prior to starting to describe in detail small molluscan faunas of Mesozoic age collected over the last several years both in northern Australia and Papua New Guinea; concurrently he prepared for the revision of Australian Cretaceous bivalves and ammonites. He completed seven manuscripts for publication and continued to update the computerized index of palaeontological references of papers dealing with Mesozoic molluscs and Ordovician graptolites of the world. The ultimate objective of Skwarko's studies is a more thorough and accurate interpretation of the Mesozoic palaeontology, palaeogeography, and biostratigraphy of Australia and Papua New Guinea.

D. L. Strusz

D. L. Strusz is engaged in a stratigraphic and palaeontological study of the A.C.T. and the surrounding districts. This region is significant for understanding the development of the Palaeozoic Lachlan Geosyncline. The stratigraphic side of the study is being advanced by co-operation with the Engineering Geology Group (BMR) and the Geological Survey of New South Wales, and by the *TANTANGARA-BRINDABELLA* Mapping Project under M. Owen.

The first palaeontological study undertaken, after the extensive collections from Canberra were put in order, was of the trilobite family Encrinuridae whose representatives are commonly found in the Silurian rocks of the region. This has involved a study of all the described species in southeastern Australia (in need of revision), and of the systematics of the family. This revisionary work is now complete and being written up. In relation, the bulk of the material from the A.C.T. Silurian has been prepared, and preliminary identification made where possible.

A second study has been started on the Silurian brachiopod faunas where much revisionary work will probably be necessary. Initially, a collection of well preserved specimens from a locality west of Canberra was selected, and opportunity taken during a visit to Europe to work on them with the help of Dr V. G. Walmsley (University College, Swansea) and Dr L. R. M. Cocks (British Museum, Natural History). The taxa present have as far as possible been identified and preliminary descriptions drafted. Most of the species appear to be new, but they will have to be checked against similar forms known in the Silurian of Yass, N.S.W. The fauna is almost certainly of Ludlovian (Late Silurian) age. Strusz also attended the Second International Symposium on Fossil Corals and Coral Reefs held in Paris 22-28 September.

J. M. Shergold

Work continued on the late Cambrian trilobite biostratigraphy of the carbonate sequences of the Burke River Structural Belt, western Queensland: systematic palaeontology of trilobites spanning the late Idamean to pre-Payntonian interval of Cambrian time in the Chatsworth area was commenced. Thirty-two taxa have been described in draft form from Mount Murray, and a further twenty-four out of a fauna of fifty have been described from Lily Creek and Horse Creek sections. At Mount Murray three faunas can be recognized: (1) pre-*Irvingella*, (2) *Irvingella*, and (3) post-*Irvingella*. Three post-*Irvingella* faunas occur at Lily and Horse Creeks and at outcrops on the blacksoil plains around Chatsworth homestead. The Idamean biostratigraphic zonation recognised by Opik around the heads of Pomegranate Creek (39 km E and NE of Mount Murray) cannot be adequately applied at Mount Murray, nor can that recognized by Henderson in the *GLEN-ORMISTON* Sheet area. The occurrence of *Irvingella tropica*, however, ties all three areas together, and can be regarded as a datum. A new Australian local stage, Iverian, is to be erected for the post-*Irvingella* faunas of the Chatsworth area. Previously recorded Asian trilobites in part constituting these faunas place the Daizanian and Changshanian Stages of Manchuria and Korea respectively in temporal perspective.

In connexion with Late Cambrian trilobite biostratigraphy and systematics, Bulletin 153, describing latest Cambrian and Early Ordovician trilobite faunas from the southern portion of the Burke River Structural Belt, and their time-stratigraphic potential, was published. Palaeoanatomical investigation on the genus *Pseudagnostus* resulted in the preparation of a reclassification of these agnostid trilobites which has been submitted for publication.

As Chairman of the IUGS Subcommission on Gondwana Stratigraphy Early Palaeozoic Working Group set up in 1973, Shergold has attempted, through information circulars, to collate information relating to the geography and geology of the margins of a now fragmented and widely dispersed proto-Gondwanaland.

Related to this activity a manuscript was prepared in co-operation with R. A. Cooper (New Zealand Geological Survey), D. I. Mackinnon (University of Canterbury), and E. L. Yochelson (US Geological Survey) which describes Late Cambrian trilobites, brachiopods, and molluscs from northern Victoria Land, Antarctica. This represents the first Late Cambrian fauna described from Antarctica, and, among other things, increases our knowledge of the geographic distribution of Late Cambrian faunas.

Collaboration with J. Pojeta Jr (US Geological Survey), who concluded his visit to Australia in May, and J. Gilbert-Tomlinson (BMR), resulted in a BMR Bulletin describing latest Cambrian and Early Ordovician rostroconch molluscs, a work which has importance in documenting the evolution of the Mollusca.

Shergold is leader for IGC Excursion 4C, Cambrian and Ordovician biostratigraphy of the eastern Georgina Basin, and has prepared a guidebook (co-authored by E. C. Druce, B. M. Radke, and J. J. Draper) and supplementary biostratigraphic synopsis; a trial run of the excursion took place in August and September.

Palaeontological examination of Georgina Basin Project materials continued. In connexion with this project, and as part-time supervisor for ANU, he examined Middle Cambrian stratigraphy of the Arthur Creek and Marqua Beds in the field during June, together with P. West (ANU Ph.D. candidate).

Miscellaneous activities included continued service on the Editorial Panel of the Association of Australasian Palaeontologists; and documentation, with K. A. Plumb and M. Z. Stefanski, of an occurrence of Middle Cambrian trilobites from the Elcho Island Formation (Wessel Group) of the Arafura Basin, Northern Territory.

Joyce Gilbert-Tomlinson

J. Gilbert-Tomlinson collaborated with J. Pojeta Jr and J. H. Shergold in preparing a Bulletin on the Cambrian and Ordovician rostroconch molluscs from northern Australia (No. 171) and with J. Pojeta Jr in a Bulletin on Australian Ordovician pelecypod molluscs (No. 174).

Bulletin 171 deals with material from the Amadeus and Georgina Basins. Of 32 species, 24 are named (21 new) and are included in 15 genera (6 new). The relative abundance of Cambrian species (11) compared with the rest of the world (4) is particularly noteworthy. Bulletin 174 treats material from Tasmania as well as the two main central Australian sedimentary basins. Of 47 species assigned to 31 genera, 27 species, 20 genera, and 1 family are new. Very few species are common to mainland Australia and Tasmania. As a supplement to Bulletin 171, 2 additional rostroconch species (from Tasmania) are named. She has in preparation a further Bulletin on the Ordovician dikelokephalinid trilobites of northern Australia in which one new family, 2 new subfamilies, and 6 new genera are named. Except for one genus, originally described from China, all the mainland genera are new.

The Wiso Basin Party was visited and Cambrian fossils were collected from the *WINNECKE CREEK*, *TENNANT CREEK*, *GREEN SWAMP WELL*, and *SOUTH LAKE WOODS* Sheet areas; and Ordovician fossils from the *LANDER RIVER* Sheet area. The stratigraphic and structural relationship of the Cambrian and Ordovician units is uncertain. Compared with those of the Amadeus Basin, the Cambrian fossils correlate with the trilobite band at the base of the Giles Creek Formation, and the only diagnostic Ordovician fossils with those of the upper Stairway Sandstone.

A brief field investigation of the Lower Cambrian sequence exposed on Neutral Junction Station (*BARROW CREEK* 1:250 000 Sheet) and mapped in 1961 by K. G. Smith as Grant Bluff Formation was made. The beds yielded an ichnofauna comparable with that of the upper part of the Arumbera Formation of the Amadeus Basin, and a fragment of an undescribed arthropod—probably a trilobite, and in that case the earliest known member of the class in Australia.

Time was spent curating early Palaeozoic material, and identifying and judging material submitted by the public.

G. C. Young

During 1975 work on Palaeozoic vertebrates has concentrated on the systematic description of extensive BMR collections from southeast and northwest Australia, and Victoria Land, Antarctica, made over the last five years. The faunas represented come from marine and non-marine strata of Ordovician to Carboniferous age. Marine occurrences include the Gogo fauna from Upper Devonian rocks in the Canning Basin, northwest Australia, the Taemas fauna from Lower Devonian limestones near Yass, N.S.W., and jawless fishes from the Ordovician Stairway Sandstone in the Amadeus Basin. The Gogo and Taemas faunas have attracted world interest for the unusually complete preservation of most groups of early fishes. Their study is being undertaken in conjunction with workers in the British Museum (Natural History). Most important results to date are the discovery of several new groups of placoderm fishes in the Taemas fauna, which are providing new information on the structure, early evolution and relationships of these organisms. The complete preservation of the Gogo specimens and their association with datable conodont assemblages is also facilitating the study of less well-preserved but widespread vertebrate occurrences in non-marine Devonian rocks throughout Australia. This aspect of the research is directed toward the delineation of biostratigraphic zones for the correlation of non-marine Devonian sequences. The first stage in this work has been carried out in conjunction with research at the Australian Museum, Sydney, and involves the description of a large collection of antiarch fishes from Victoria Land, Antarctica. A number of new Antarctic species of the antiarch *Bothriolepis* show affinities with Australian and southern Chinese occurrences. This work has been extended to cover an extensive collection of *Bothriolepis* remains made by BMR from a new locality discovered in 1973 in the Harajica Sandstone of the Amadeus Basin, central Australia.

D. J. Belford

The systematic study and illustration of Tertiary foraminifera from the *BLUCHER RANGE* and *WABAG* 1:250 000 Sheet areas continued.

This study follows the completion of regional mapping in these sheet areas and is intended to illustrate and document the faunas on which age determinations were based.

Illustration of the planktonic foraminifera has been completed, and sectioning and photography of the larger benthonic foraminifera are progressing. Support was given to the Papua New Guinea Geological Survey through the year, mainly with samples from the Schrader Range and the Marum Complex. New species of the foraminiferal genus *Triplasia* were described from Miocene beds in the Wabag area, and the wall structure studied; it has been concluded that the pseudolabyrinthic test wall reported in this genus is not a primary structure.

A new foraminiferal genus referable to the super-family Miliolacea has been found in the Chimbu Limestone (Eocene); it is being studied in conjunction with Dr C. G. Adams, British Museum (Natural History).

In conjunction with Dr Viera Scheibner of the New South Wales Geological Survey manuscripts were sought from friends and colleagues of Dr Irene Crespin, for the preparation of a Crespin Commemorative Volume, on the occasion of her 80th birthday; this volume will appear as part of the Bureau of Mineral Resources Bulletin series, and is now being compiled.

Establishment of the ESCAP fossil reference collection continued with additional foraminiferal species being deposited, and also casts and moulds of brachiopod species from the collection of the Department of Geology, University of New England.

P. J. Jones

The study of the Lower Carboniferous Ostracoda from the Bonaparte Gulf Basin, part of the BMR overall project on the geology and palaeontology of this basin, was undertaken in order to describe the ostracod species, to determine their stratigraphical ranges, and to evaluate their biostratigraphy for both local and intercontinental correlation. The subject was in particular need of study because, in contrast to the many published works on the taxonomy and biostratigraphy of Carboniferous Ostracoda from the Northern Hemisphere, virtually nothing was known from the southern continents.

Work during 1975 included the recognition of a provisional scheme of eleven ostracod biozones for the Lower Carboniferous sequence of the Bonaparte Gulf Basin. Some of the Tournaisian zones are used in determining correlations within the southeastern platform of the basin, and are recognized in the Laurel Formation of the northern Canning Basin. The Visean zones are used to establish correlations between the platform and the basinal provinces of the Bonaparte Gulf Basin. Biogeographically, the faunas, despite their presumed benthonic habitat, contain several Early Carboniferous cosmopolitan species, and have affinities with faunas in USSR, Europe, and (mainly Cordilleran) North America. This project, completed as a Ph.D. thesis submitted to the University of London, is now being prepared for publication as a BMR Bulletin.

A check list of Ostracoda recorded from Australia and Papua New Guinea (1845-1973) was completed as a joint project with P. de Dekker (Dept. of Geology, University of Newcastle), and submitted for publication. This report is a bibliographical tool for workers engaged in ostracod research, and represents the Australian contribution to the International Palaeontological Association Study Group project—'Shallow marine and freshwater Ostracoda of Tethys'.

A paper was prepared in collaboration with Dr J. Roberts (School of Applied Geology, University of New South Wales) entitled—'Some aspects of Carboniferous biostratigraphy in eastern Australia: a review of recent progress and problems'. This report was prepared in response to a request from the chairman of the Dinantian working group of the International Subcommission on Carboniferous Stratigraphy (SCCS) in order to present the latest results from Australian research in Early Carboniferous stratigraphy at the International Congress on Carboniferous Stratigraphy and Geology, in Moscow, September 1975.

In order to conclude the project on the Lower Carboniferous Ostracoda from the Bonaparte Gulf Basin, it was necessary to study first-hand comparative material from Britain and the USSR. Two months (August, September 1975) were spent overseas, partly for this purpose, when reference collections were studied at the British Museum (Natural History), University College, London, the Hancock Museum in Newcastle-upon-Tyne, the All Union Institute of Petroleum Research (VNII) in Moscow, and the Academy of Science, Institute of Geology and Geophysics in Novosibirsk. Problems on ostracod taxonomy and classification, and intercontinental correlation of Carboniferous rocks were discussed with workers at these institutions. Samples were collected from many reference sections of Lower Carboniferous (Dinantian) rocks in Belgium, and to a lesser extent in the Federal Republic of Germany and northern France, with the co-operation of Belgian, Dutch, and German colleagues.

Two reports were delivered to the International Congress on Carboniferous Stratigraphy and Geology in Moscow—(i) to the Palaeontology and Stratigraphy section on the palaeobiogeographical affinities of the Lower Carboniferous Ostracoda from the Bonaparte Gulf Basin, and (ii) to the SCCS, as mentioned above. Pre- and post-Congress field excursions were attended in the South Urals (Bashkiria) and the Moscow Basin. Samples collected from both regions were taken from reference sections of the Carboniferous (e.g., the Bashkirian and Moscovian stages).

Many microfossil groups (including ostracods) have been described from the type sections of the Carboniferous rocks in Belgium and the USSR, and specimens obtained from the samples collected will be added to the BMR collections.

D. Burger

The study of the Lower Cretaceous palynology of the Surat Basin, Queensland was virtually completed. The systematic and descriptive study of spores, pollen grains, dinoflagellates, from information based on studies of modern microplankton overseas, resulted in new classificatory procedures designed for the Australian fossil microplankton. The occurrence of several species demonstrates the restricted (shallow to brackish) environments for plankton life during the Aptian and early Albian.

Statistical (numerical) analysis of fossil assemblages, particularly of spores and dinoflagellates, allowed the interpretation of palaeo-environments at various times, and the advance and retreat of the Aptian inland sea was traced. Acritarchs, a little-known group in terms of environment, show little change with successive changes of the environment.

Detailed palynostratigraphic work, including re-examination of older material, resulted in a new interpretation of sections drilled by the Bureau (Coreena-Surat-Griman Creek), and gave a clearer insight into the depositional history during the Albian.

Integration of the dinoflagellate sequence of the Surat Basin and the Eromanga Basin (studied in the Geological Survey of New South Wales) led to a unified zonal system for the Great Artesian Basin, which is expected to be applicable in the Morehead and Papuan Basins.

The basal Albian rock sequence has yielded species of *Clavatipollenites* and *Asteropollis* which are only known from younger Albian sediments overseas. Their relatively old age could indicate that Australia may have been important in the early development of the angiosperms.

M. R. Walter

Georgina Basin project. The lithology and palaeontology of the late Precambrian and Early Cambrian sediments of the following 1:250 000 Sheet areas were studied: western *MOUNT WHELAN*, *HAY RIVER*, *TOBERMORY* and central and eastern *HUCKITTA*. The lithostratigraphic results are described elsewhere in this summary. Trace fossils are abundant in the Mount Baldwin Formation of the Jervois Range, and compare closely with those of the latest Precambrian/Early Cambrian Arumbera Sandstone of the Amadeus Basin. Dolomites in the upper Grant Bluff Formation in the *HUCKITTA* Sheet area and the Field River Beds of the *HAY RIVER* Sheet area contain columnar branching stromatolites the study of which is expected to aid correlation with the Amadeus Basin.

Nabberu Basin microfossils and stromatolites. Microfossils are abundant in ferruginous cherty oncolites from a granular iron formation in this basin. At least five species have been recognized, and these also occur in the early Proterozoic Gunflint Iron Formation of Canada. This microbiota was described at the First Australian Geological Convention ('Proterozoic Geology') in Adelaide and at the International Geological Correlation Program meeting ('Correlation of the Precambrian') in Moscow.

Amadeus Basin Precambrian fossils. Study has commenced of a newly discovered latest Precambrian microbiota in cherts of the Julie Member, Pertatataka Formation. The microbiota consists of poorly preserved filamentous and unicellular microfossils. Possible metazoan burrows from the Julie Member have been shown to be nonbiogenic water-escape structures. The study of Precambrian stromatolites from the Amadeus Basin is continuing.

McArthur Basin stromatolites. A large collection of *Conophyton* stromatolites was made this year to supplement earlier collections; they will be studied in 1976.

Editing 'STROMATOLITES', a book to be published by Elsevier. The edited manuscript of the book was sent to the printer on 20 October. The book contains 44 chapters, 4 appendices, and a bibliography with 2050 entries. There are 41 contributors. The total length is expected to be about 750 pages. Publication is expected next year.

Overseas visit. Two months were spent in Europe. During three weeks in Russia the International Geological Correlation Program conference 'Correlation of the Precambrian' was attended and two papers were presented. Field trips were made to the Bashkirian Urals to study the late Precambrian sediments and stromatolites and to central Russia to study the banded iron formation in two of the largest open-cut mines.

Three weeks were spent in Britain studying the late Precambrian and Early Cambrian sediments in Scotland, Wales, and England and at Imperial College, London looking at microfossils from the Scottish Precambrian. Discussions were held with Dr Charles Downie of the University of Sheffield about Precambrian acritarchs.

During two and a half weeks in West Germany two papers were presented at the International Symposium on Fossil Algae, and stromatolites and fossil algae were collected on field trips to the Austrian Alps and southern Germany.

Several days were spent with Professor Claude Monty in the University of Liege, Belgium, discussing stromatolite problems.

Co-operation with both BMR and the Baas Becking Laboratory is continuing at Imperial College, London, where attention has been focused on Precambrian fossils from the

McArthur Group (M. D. Muir), Roper Group (C. J. Peat), Bungle Bungle Dolomite (W. L. Diver), and Mount Bruce Supergroup (M. D. Muir). Major descriptive papers on several microbiotas are in preparation.

E. M. Truswell (formerly Kemp)

In 1975 a series of papers dealing with the palynology of Early Tertiary sediments on the Ninetyeast Ridge, Indian Ocean, was completed. This work, which was carried out in conjunction with W. K. Harris, of the South Australia Mines Department, is described more fully under the section headed DEEP-SEA DRILLING. A short paper dealing with the Tertiary vegetation history of Antarctica is described under the same heading.

Research is presently under way on the systematic palynology of the oldest part of the Permo-Carboniferous sequence in the Galilee Basin, Queensland. These studies are being carried out in co-operation with members of the Geological Survey of Queensland. BMR participation in the project involves, initially, detailed analysis of the Joe Joe Group, with the dual aim of describing the microfloras present and utilizing them in the stratigraphic subdivision of the interval. This work elaborates the previous studies of Norvick (BMR Record 1974/41 (unpubl.)).

Investigations into aspects of the Permo-Carboniferous palynology of Tasmania have continued, with the examination of microfloras from diamond-drill holes at Andersons Creek, near Beaconsfield. Microfloras from the lower parts of the Masseys Creek Group at this locality are markedly similar to those known from the Quamby Mudstone and lower Golden Valley Group at Golden Valley. The Tasmanian data on palynomorph distribution in the Permo-Carboniferous are particularly useful because of the excellent faunal control available for most sections. Hence, new data on the ranges of stratigraphically useful form-species have come to hand; *Verricosisporites pseudoreticulatus*, for instance, which was formerly regarded as defining the base of Stage 3 in the zonal scheme of Evans (*Gondwana Stratigraphy* 2, UNESCO, Paris, 41-54, 1969) can now be observed to make a first appearance much lower in the Permian sequence, viz. in Faunizone 1 of the Tasmanian scheme (Clarke & Banks, *In*: K. S. W. Campbell, Ed., *Gondwana Geology*, A.N.U. Press, 453-66, 1975).

A pilot study designed to test the feasibility of using palynology to correlate well sections in the early Palaeozoic of the Georgina Basin was initiated. Material from AOD Ethabuka No. 1 well, in intervals designated Mithaka Formation (Middle Ordovician) and 'Ethabuka Beds' yielded abundant and diverse acritarchs in variable stages of preservation. Samples from Late Cambrian carbonaceous limestone in BMR drillholes Boulia Nos. 6 and 8, however, yielded only hyaline spheres of probable algal origin, which are of doubtful stratigraphic value. Outcrop samples of bituminous limestones of the Ninmaroo Formation, collected during a visit to the Georgina Basin in August, similarly failed to yield useful microfossils.

An assemblage of Tertiary pollens from BMR Napperby No. 1 in the northern part of the Ngalia Basin, Northern Territory, was described. This suite, which was recovered from a lignitic interval, provides the first firm dating of Early Tertiary sequences in this part of central Australia; comparison with palynological zonal schemes established in southern Australia suggests a middle Eocene age. The palynomorph assemblage resembles those which have been described from the Eyre Formation of northern South Australia (Wopfner, H., Callen, R., & Harris, W. K.—1974, *J. geol. Soc. Aust.* 21, 17-51, 1974), and included non-marine dinoflagellate cysts and abundant pollen of aquatic plant groups, suggesting deposition in a lacustrine environment. Relatively high *Nothofagus* pollen counts suggest that humid conditions prevailed at least locally at this mid-continent site in the Eocene. Further investigations on lignites from Hale River and Tempe Downs are planned.

Robert S. Nicoll

The biostratigraphic conodont study of the Fairfield Group, Canning Basin, Western Australia, was completed in first draft and the examination of Upper Devonian sections from the Oscar and Napier Ranges has commenced. A paper on the 'Effects of Late Carboniferous-Early Permian glaciation on the distribution of conodonts in Australia' was presented at the symposium on Conodont Palaeoecology at Waterloo, Ontario, Canada.

The paper discussed the lack of Permian conodonts in Australia and was based principally on studies in the Carnarvon Basin, W.A. The opportunity was taken to collect conodont-bearing material from Ordovician, Silurian, and Devonian type localities in Ontario for the BMR reference collections.

In co-operation with the Tantangara Party several sections and some miscellaneous samples were collected from the *BRINDABELLA* 1:100 000 Sheet area for age determination.

G. C. H. Chaproniere

The biostratigraphic and systematic study of Oligo-Miocene large foraminifera from northwestern Western Australia was almost completed.

A study of the larger foraminifera from Victoria has been initiated, with a study of topotypic material of *Lepidocyclina howchini*. This species was described by Chapman & Crespin in 1932 from a borehole near Hamilton. The object of this study is to redescribe this form in greater detail than formerly and to gain a better knowledge of its morphological changes with time. The variation of this and other species of larger foraminifera throughout the Victorian late early Miocene will be studied following a field visit planned for early 1976.

A paper discussing palaeoecology of the larger foraminifera is shortly to be published in *Alcheringa*. A second paper describing a new limestone unit from Western Australia has been submitted for publication in the BMR Journal.

S. Shafik

Bonaparte Gulf Basin. A reconnaissance investigation has been made of the nannofossil distribution in core material and ditch cuttings from the Ashmore Reef No. 1 well, in order to study the Tertiary sequences of northwestern Australia. Rich and well-preserved assemblages were recovered from the upper Oligocene/lower Miocene part of the sequence. This prompted a detailed examination of the nature of the Oligocene-Miocene transition in the sequence; several nannofossil biostratigraphic zones are recognized. Correlation of preliminary nannofossil results with those of the planktic foraminifera indicates that the *Globigerinoides* datum is probably diachronous and late Oligocene in age in the studied section. Additional material pertaining to the Oligocene-Miocene boundary was examined from New Guinea. The study will incorporate systematics and is expected to be concluded early in 1977.

Eucla Basin. Study of material from this basin concentrated mainly on dating the advent of the Eocene marine transgression. It resulted in placing the base of the marine Tertiary sequence above the *Reticulofenestra scissura* nannofossil datum and below the extinction horizon of *Chiasmolithus grandis*. This indicates a correlation younger than the base of the planktic foraminiferal Zone P13.

Other conclusions reached in this study are—(1) the vertical ranges of the planktic foraminifera *Subhotina frontisa*, *S. higgusi* and *Morozovella densa* are extended above the base of Zone P13; (2) The abundance of *Reticulofenestra hampdenensis* increases in an easterly direction on the Australian southern margin; (3) the lower part of the Tertiary sequence in the Eucla Basin was deposited in a shallow environment rich in nutrients; (4) reworked nannofossil forms are recorded and it is thought that the Naturaliste Plateau fits well as a western source area for these forms.

Perth Basin. Investigation of nannofossils extracted from the Kings Park Formation in several localities indicates—

1. the *Heliolithus riedelii* Zone and the lower part of the *Discoaster multiradiatus* Zone are present; a correlation of these two zones with the planktonic foraminiferal zone P4, confirms previous foraminiferal studies;
2. the presence of a lower Eocene marine horizon in the Perth metropolitan area;
3. the occurrence of a mid-middle Eocene marine horizon in the basin;
4. displaced Upper Cretaceous nannofossils occur in most of the Kings Park Formation, indicating a possible transportation from inshore marine Cretaceous sediments.

Eastern Tasmania and Bass Strait. Five sets of core samples collected by the Marine Geology Group were shown, by cursory examination, to be Quaternary. A more precise dating awaits installation of the SEM.

Micropalaeontology Laboratory

F. Hadzel, A. T. Wilson, P. W. Davis, L.

Kraciuk, P. Harrison (to June), and Trainee Technical Officers.

1763 samples were washed in the micropalaeontological laboratory, and 1073 thin sections prepared from 804 samples; 79 samples were polished for examination. 894 slides were prepared for nannofossil study from 673 samples.

In the Acid Laboratory, Fyshwick, 750 samples with a total weight of 1600 kg were digested in acid for conodont extraction. An additional 300 samples with a total weight of 600 kg were treated in the field in the mobile conodont laboratory. 700 samples were picked for conodonts, and 132 for foraminifera, 3500 photographs were taken, and 36 pages from different publications were translated from German. 140 samples were processed in the palynology laboratory.

OTHER SEDIMENTARY SECTION ACTIVITIES

COMPUTING GROUP, BY K. LONG

STAFF: W. Mayo (to August), K. Long

New programming

The following additions were made to the Geological Branch program library, GEOLPROGS:

1. LINES, a program for the analysis of the length and direction of fracture traces.
2. Expansion of the polynomial regression program to include a test for the significance of the reduction in sum of squares due to the addition of each term in the polynomial.
3. Modification of the sorting program in the SURFAUST system to optionally produce the printed output in a format suitable for bibliographic data.
4. Addition of a redundancy measure and chi-square significance test to the canonical correlation program.

GEOLPROGS now consists of over fifty programs and subroutines stored in UPDATE format on magnetic tape. The UPDATE system provides convenient storage of the library in a form which is easily updated and at the same time allows ready access to individual programs through the use of a few standard control cards. Instructions on the use of each of these programs, together with control cards and data required, are explained fully in the GEOLDOCS documentation set (see below).

GEOLDOCS documentation set

The Geological Branch program documentation set, GEOLDOCS, has been considerably updated and will soon be available in the form of a publication. Originally, each program was documented in computer card form, and program OUTREC was used to obtain listings under the headings Author, Keywords, Purpose, and Driving Instructions, in BMR Record format. The set is now also stored on magnetic tape in UPDATE format for ease of use, and example data decks and corresponding example output for most of the programs have been added. A description of the use of the documentation set, and explanations of variable formats and various computing terms, form an introduction to the publication. Program OUTREC may still be used to obtain computer listings and a separate heading for references has been added.

As many geologists have attended introductory computer courses or FORTRAN programming courses over the last year, the GEOLDOCS set should enable them to process their data by computer with a minimum of assistance.

Storage and retrieval

A system of indexing the whereabouts of geological data has been devised to replace the existing sample submission system. The SURFAUST system (upon which the sample submission system is based) which the sample submission system is based) is not suitable as a central storage-retrieval system, and it is hoped that an index as proposed will halt the loss of valuable geological data in the short term.

Data are to be indexed on a project basis under headings such as sheet areas sampled, publications arising out of the project, where data and samples are stored, and the type of data stored. A search of the index will produce a list of projects and where the various items of data for each project are stored. The user must then look for the particular samples or data he requires. Thus, the major part of the work-load is shifted from the collector of the samples to the person who wishes to use them at a later date.

The indexing system is linked to a set of 'project boxes' where items such as field note books, photo overlays, and locality maps may be stored after the completion of a project. Items in project boxes are included in the index, as are raw data contained in publications. Data to be indexed must be in a form suitable for long-term storage. Thus, even though computer based storage-retrieval systems may be used for individual projects, a magnetic tape is not a suitable form for long-term storage of data, and a listing must be included in the project box.

INTERNATIONAL GEOLOGICAL CONGRESS

Various members of the Sedimentary Section, as in 1974, were involved in preparatory work for the IGC excursions to be conducted in August 1976.

M. J. Jackson has been involved with the co-ordination and costing of all excursions to be run in Australia. A. T. Wells and J. Kennard investigated the route over which the excursion in the Amadeus Basin will be conducted, and prepared an excursion guide book.

Members of the Georgina Basin Party (E. C. Druce, J. Shergold, B. Radke, and J. Draper) prepared a guide book and conducted a trial run of their excursion through the Georgina Basin with participants from the Geological Survey of Queensland and companies.

A. R. Jensen and N. F. Exon, together with J. Anderson and W. Koppe of the Geological Survey of Queensland, wrote a guide book for the excursion through the Bowen Basin. J. M. Dickins and D. Burger wrote appendices for the same publication on aspects of the Permian and Cretaceous palaeontology.

M. Plane visited the Tirari Desert area of northeastern South Australia to ascertain travel conditions for a post-Congress field excursion.

ESCAP STRATIGRAPHIC ATLAS PROJECT, BY A. MOND

A project to prepare a stratigraphic atlas of the ESCAP region (Economic and Social Commission for Asia and the Pacific; originally ECAFE) was initiated a decade ago but it was only recently that a Working Group on Stratigraphic Correlation between the Sedimentary Basins of the region adopted standard time-scales and references for the atlas.

Stratigraphic correlation diagrams for the project have been compiled for the Sydney Basin by S. J. Mayne and are now ready for drafting. In September-October A. Mond worked on stratigraphic correlation diagrams for the Carnarvon Basin, in co-operation with the Petroleum Exploration Branch's Regional Basin Study Group. Thirty petroleum exploration wells (mostly offshore) have been compiled in the standard format. The correlation diagrams will improve understanding of stratigraphic relations within the basin and copies will be incorporated into syntheses of sedimentary basins carried out by the Regional Basin Study Group.

TRAINING

Several members of the Section were nominated for courses at the Australian Mineral Foundation. A. N. Yeates attended Professor D. M. Boyd's 'Geophysics for Geologists', J. J. Draper Dr A. S. Joyce's 'Geochemical Exploration', and M. J. Jackson and J. Smart the course 'Stratigraphic Principles and Practices in Fossil Fuel Exploration' presented by Professor R. J. Weimer. J. Smart also took part in the Fifth Underground Water School organised by TCUW at AMF.

C. E. Maffi, W. J. Perry, C. J. Simpson, and J. Smart attended Departmental introductory courses on Data Processing, J. Kennard an induction course and W. J. Perry a course on interviewing techniques, all presented by the Training Section, Department of Minerals and Energy.

At CCAE, R. S. Abell took a course in Computer Programming, and J. J. Draper, K. A. Heighway, and C. E. Maffi attended a course in Basic Fortran.

METALLIFEROUS SECTION

Officer-in-charge: W. B. DALLWITZ

GEOLOGICAL INVESTIGATIONS IN NORTHERN TERRITORY, WESTERN AUSTRALIA, AND ANTARCTICA

Supervising Geologists: R. G. DODSON (until late August), K. A. PLUMB (to 31 October)

ARUNTA BLOCK, BY A. J. STEWART, R. G. WARREN, A. P. LANGWORTHY, & L. A. OFFE

STAFF: R. D. Shaw (Overseas from 12 Sept.), A. J. Stewart, R. G. Warren, A. P. Langworthy, L. A. Offe, L. P. Black (part time), and A. Y. Glikson (part time); M. J. Rickard (ANU), Prof. B. E. Hobbs, V. Hirsinger, J. Wilkie, and J. Fitzgerald (all of Monash University), R. W. Marjoribanks (University of Adelaide), and D. B. Clarke (Geological Survey of N.T.) are associated with the project

Introduction

The objectives of the current geological program in the Arunta Block are:

1. To determine the geological history of the Arunta Block, and its relation to the surrounding tectonic units.

2. To assess the economic potential of the Arunta Block in terms of mineral deposits and water resources.

3. To publish coloured geological maps for use in mineral exploration: 1:100 000 scale is being used in areas of good exposure, and 1:250 000 scale in areas of poor exposure.

Before BMR began systematic mapping of the Arunta Block in 1970, geological knowledge of the area was disjointed and meagre, and geological understanding poor. The Arunta 'Complex' (as it was called) was known to comprise Precambrian moderate to high-grade metamorphic rocks and granite, and was considered by some to be of Archaean age. The only systematic geological mapping had been carried out in the Harts Range in the eastern part of the area by Joklik, of BMR, in the 1950s; he recognized several metasedimentary gneiss units, a large mass of amphibolite, and metamorphosed felsic and mafic igneous rocks.

Regional mapping by BMR, in the 1960s, of the late Proterozoic to Palaeozoic sedimentary basins that flank or overlie the Arunta Block, had identified late Palaeozoic thrust faults with displacements of tens of kilometres in the Arunta Block at the margins of the sedimentary basins. Concurrent regional gravity surveys had discovered a number of latitudinally-trending gravity anomaly ridges of very large relief (up to 170 mGal) extending throughout the area. A few isotopic dates had been determined by various university laboratories; only one reliable whole-rock Rb-Sr isochron existed (1690 m.y. on the Jinka Granite), and some Rb-Sr and K-Ar mineral dates (1840, 1130, 1040, 420, 410, 400, and 361 m.y.) had been obtained. The area had produced gold and mica in the past, and numerous other small mineral deposits, mainly of copper and tungsten, were known to exist.

Since the current project began in 1970, 14½ 1:100 000 Sheet areas and five 1:250 000 Sheet areas have been surveyed on the ground, leaving 7½ 1:100 000 Sheet areas still to be mapped (Fig. M2); four 1:250 000 Sheet areas also remain to be mapped (*HUCKITTA*, *BARROW CREEK*, *MOUNT LIEBIG*, and *MOUNT RENNIE*). Preliminary Editions of two 1:100 000 Sheets have been issued, two are being printed, one is being drafted, and two have been compiled and reduced to 1:100 000 scale in readiness for drafting. One First Edition and two Preliminary Editions of 1:250 000 Sheets have been issued, and the First Editions of the two Preliminary sheets are in preparation. Two reports which will present all the geological data gathered during the mapping and their interpretation are being prepared, and a third is being edited.

The major advances in geological understanding of the Arunta Block since 1970 have been the following:

1. At least three major stratigraphic subdivisions of the metamorphic rocks have been recognized; the first and second subdivisions

are separated by major discordances (which are commonly very difficult to recognize where, for example, a metamorphic episode has affected rocks on both sides of a fault or unconformity), and the second and third by a clear angular unconformity. The three groups show a chemical evolutionary sequence from compositions corresponding to mafic and felsic igneous rocks, through mixed pelitic and psammitic sediments, to a quartzite-shale-carbonate sequence, respectively. The second and third subdivisions are lithologically correlated with similar sequences in the Tennant Creek and The Granites-Tanami areas, and all three areas are intruded by granites of similar age.

2. Synthesis of the geological mapping and quantitative density modelling of the gravity data have led to a hypothesis of the tectonics of the region which postulates at least two orogenic cycles during the Precambrian. The cycles involved periods of subsidence, folding, regional metamorphism, and partial melting which resulted in the formation of granite batholiths and granulitic residues, followed by upfaulting of the granulites to near-surface levels.

3. Further interpretation of the gravity data has led to the recognition of a major north-northwest-trending lineament (the Woolanga Lineament) in the eastern part of the Arunta Block (Fig. M3), and the geological mapping has located numerous major faults on the ground which coincide with or diverge from the gravity lineament; movements on these faults have occurred at various times during the Precambrian and Palaeozoic.

4. Detailed studies of areas affected by the

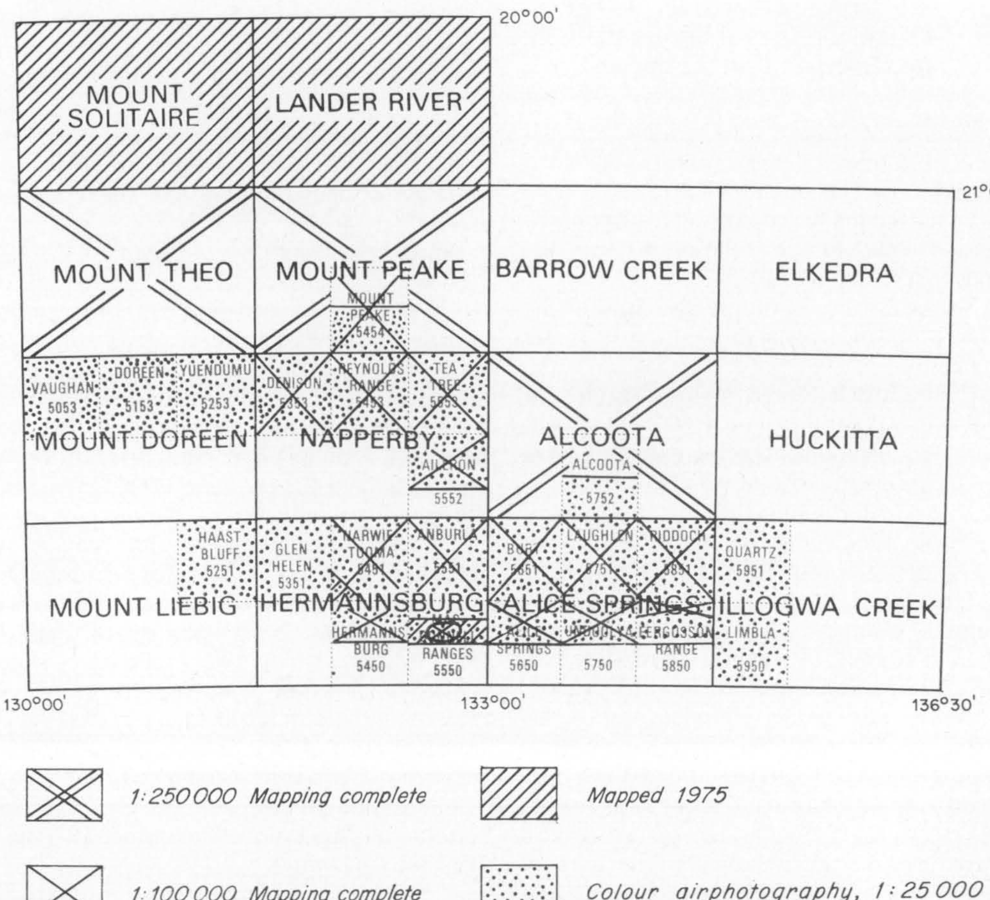


Figure M2 Arunta project: coverage of geological mapping and colour photographs

late Palaeozoic thrust-faulting have shown it to be of considerable complexity in some places, several thrust sheets being stacked upon one another. Penetrative deformation and low-grade metamorphism of these areas were also important during the late Palaeozoic, and contemporaneous partial or complete resetting of mineral ages throughout much of the Arunta Block suggests widespread heating at that time; in the Harts Range, the heating was sufficiently intense to cause local partial melting, as shown by the formation of pegmatite veins.

5. Rb-Sr whole-rock dating by Black has suggested the existence of two episodes of widespread high-grade regional metamorphism during the Proterozoic—the first around 1800 m.y. and the second around 1700 m.y.—and of several episodes of granite emplacement between 1700 and 1000 m.y. In addition, migmatization around 1100 m.y. has been identified in the southern part of the Block. No Archaean age has as yet been identified.

6. Data on nearly one hundred mineral deposits have been collated and issued as a Record as the first step of an economic appraisal of the Arunta Block. Small stratabound copper deposits are common along a magnesium-rich horizon in the first major stratigraphic subdivision. Metasomatic or hydrothermal deposits of tungsten and copper are particularly common in the second stratigraphic subdivision, especially in the vicinity of granite masses. The area is also a repository for uranium in deposits within the Palaeozoic and Cainozoic sedimentary rocks overlying the Arunta Block.

Investigation of mineral deposits (Warren)

Compared to other geologically similar regions, the Arunta Block contains few known mineral deposits, and those which are known are mostly uneconomic. This may be because of the low level of exploration effort, the remoteness and aridity of the area, and the previous lack of geological information. The remoteness and climate will continue to hinder mining, but the increasing amount of geological information should encourage further and more efficient exploration for mineral deposits.

The most valuable mineral so far produced from the Arunta area has been mica, although mining ceased in 1961. The Home of Bullion copper mine operated successfully during the 1930s. The Jervois copper-lead-zinc lodes have been the subject of several ambitious but unsuccessful or partly unsuccessful ventures since their discovery in 1929. Most successful ventures in the Arunta Block have involved a few miners working small, rich deposits. At the time of writing, two mines (Mount Hardy—copper; and Molyhil—tungsten) were being worked in the area; two ventures (Jervois—copper; Jericho—tungsten) were under care-and-maintenance; and several prospects (Oonagalabi—copper-lead-zinc; Jinka—fluorite; Mount Larrie—copper; and Wolfram Hill—tungsten) were being evaluated. Exploration has virtually ceased for the time being, mainly because of administrative and economic factors.

The Arunta Block can be subdivided into northern and southern zones by an east-west line extending from the Plenty River Plain through the Ngalia Basin. The southern zone contains most of the old mica mines, a large number of very small base-metal deposits, and the abandoned gold mines of the Arltunga-Winnecke area. It consists of felsic, pelitic, and mafic granulites and gneisses, and minor calc-silicate rock and marble. The best exploration targets are base-metal deposits of the Oonagalabi type, which occur with magnesium-rich bands in felsic gneiss; these bands are characterized by forsterite marble and gneisses containing anthophyllite, phlogopite, and spinel. The deposits appear to be stratigraphically controlled, and the best method of exploration should involve geochemical and geophysical surveys over lithologically and stratigraphically similar areas. One such deposit was geochemically sampled during the 1975 field season.

The northern zone, extending from the Jervois Range to the Western Australian border, contains the Jervois lodes, numerous copper lodes in faults (Home of Bullion being the largest), and many small tin-tungsten-tantalum deposits. It consists of pelitic, quartzose, and calcareous metasediments intruded by numerous granites. Large copper lodes in faults could be present in the area, even though most known copper prospects have already been examined by companies or by the Northern Territory Mines Branch. The

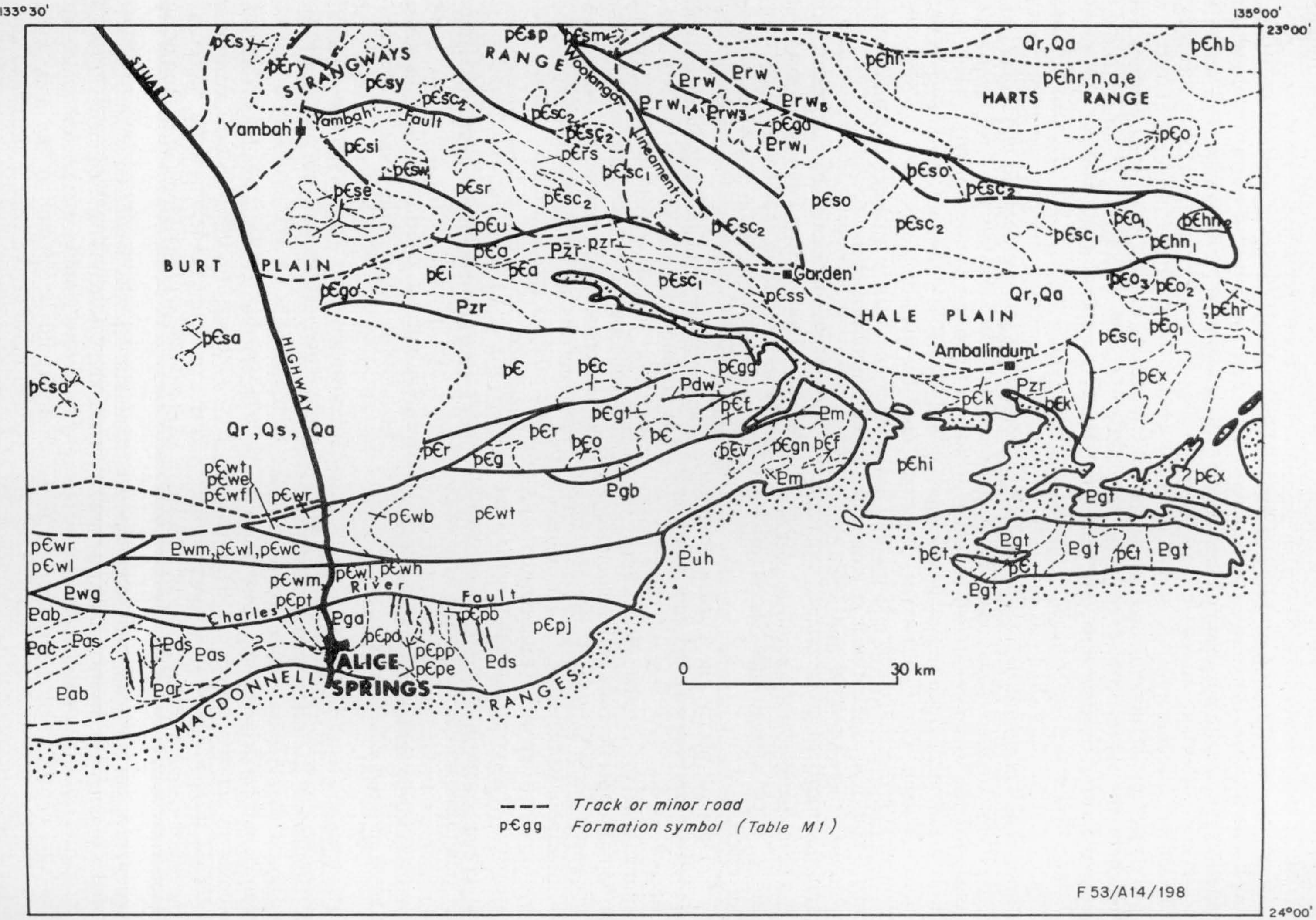


Figure M3 Generalized geological map of the Arunta Block, Alice Springs 1:250 000 Sheet area (rock units are listed in Table M1) most promising recent mineral finds are the numerous scheelite lodes of the Bonya district. These occur in calc-silicate rocks, and include deposits such as Molyhil and Jericho, which are clearly associated with granite intrusions, and several stratabound deposits such as Samarkand and Marrakesh. Taking into account the widespread extent in the northern Arunta Block of both calc-silicate rocks and known tungsten deposits, it is possible that many more deposits of this type will be found.

Record 1974/117, 'Summary of information on mineral deposits in the Arunta Complex, Alice Springs area, Northern Territory' was printed and distributed.

HERMANNSBURG 1:250 000 Sheet area

Only the four eastern and central 1:100 000 Sheet areas have so far been included in the mapping program; the *GLEN HELEN* Sheet area (in the northwest) may be included later; the *GOSSES BLUFF* Sheet area (in the southwest) consists almost wholly of sedimentary rocks of the Amadeus Basin.

ANBURLA 1:100 000 Sheet area (Glikson). Field work was completed in 1974, and photo-overlays are being prepared.

NARWIETOOMA 1:100 000 Sheet area (Glikson). Mapping of the accessible parts of the Sheet area was completed during the 1975 field season, and the results are presented in the report for the Petrological Laboratory.

MACDONNELL Ranges 1:100 000 Sheet area (Offe; Hobbs and students). Mapping of the southern half of the basement rocks of the Sheet area was completed during the 1975 field season. The rocks comprise metapelite and metasandstone overlain by the Chewings Range Quartzite and intruded by several gneissic granite bodies. They have tentatively been divided into six units (Fig. M4):

1. Fine-grained metasedimentary gneiss and minor para-amphibolite crop out in the southeastern to south-central part of the Sheet area. Tight folds are visible in some places.

2. Augen gneiss, fine-grained gneiss, and amphibolite crop out northwest of the first unit, and are separated from it by a shear zone. The unit may be stratigraphically equivalent to the first unit, although it comprises both metasedimentary and meta-igneous rocks.

3. The Chewings Range Quartzite overlies the first two units. It can be divided locally into two rock-types: massive coarse-grained recrystallized quartzite and quartz phyllite. Folding phases are difficult to delineate in outcrop pattern, but generally there is an *en echelon* arrangement of massive quartzite outcrops separated by quartz phyllite. Two phases of folding have been recognized in the quartzite, and in some areas structural evidence suggests three periods of folding.

4. Augen gneiss intrudes the first unit in the southeastern part of the Sheet area.

5. Laminated gneiss in the central part of the area intrudes the second and third units.

6. Leucocratic gneiss in the central and western parts of the area intrudes the second unit.

The first, second, and third units have undergone at least two phases of folding. The first folds are isoclinal and mesoscopic, and have been folded by open macroscopic folds. Detailed mapping in some areas delineated tight macroscopic folds, with amplitudes of about 1 km, related to the first phase of folding. The meta-igneous units (4, 5, and 6) may have intruded the first three units between the first and second folding episodes.

HERMANNSBURG 1:100 000 Sheet area (Marjoribanks). The Sheet area was mapped in 1971 and 1972, and the results have been written up in Record 1975/13, 'Structural and metamorphic geology of the Ormiston area, central Australia', which is now ready for printing. The Preliminary Edition of the *HERMANNSBURG* 1:100 000 map was printed and distributed.

ALICE SPRINGS 1:250 000 Sheet area

Ground surveys of the Arunta Block in all six 1:100 000 Sheet areas have been completed, and writing of a report on the results is in progress. The rocks in the six sheet areas have an extremely complex history involving multiple deformation, metamorphism, migmatization, and faulting, and so the usual stratigraphic criteria for a formation, such as top and bottom, facing, etc., are not preserved. Purely lithologic units have been mapped where practicable, and grouped into formations or complexes (Fig. M5). A formation for our purposes is defined as a rock unit whose boundaries can be defined, and which can be mapped (and represented on a 1:100 000-scale map) over a length equal to at least four times its thickness. A complex is defined as a diverse group of formations or rock units characterized by very complex structure, but possessing some significant unifying feature such as chemical composition or metamorphic grade. The progress in each 1:100 000 sheet area is as follows:

ALICE SPRINGS (Offe). Part of the Sheet area was checked during the 1975 field season, and formation symbols finalised. Drafting of the Preliminary Edition awaits the availability of a draftsman.

BURT (Langworthy). Drafting of the Preliminary Edition awaits the availability of a draftsman.

LAUGHLEN (Langworthy, Shaw). The Mordor Igneous Complex, an intrusion of potassic intermediate to ultrabasic rocks situated in the southeastern corner of the Sheet area, was further examined and sampled during the 1975 field season, and a paper for external publication entitled 'The Mordor Complex: a potassic ultrabasic to intermediate intrusion with kimberlitic affinities, cental Australia' is in preparation. Ultrabasic rocks, first located in 1968 about 10 km southwest of the Mordor Complex, were re-examined during the 1975 field season, and found to be similar to the Mordor rocks.

Drafting of the Preliminary Edition is in progress.

RIDDOCH (Shaw, Rickard). Preparation of photo-overlays is still in progress.

UNDOOLYA (Offe, Shaw). Mapping was completed during the 1975 field season, and photo-overlays are being prepared.

FERGUSSON RANGE (Stewart). Preparation of photo-overlays is almost complete.

Summary of Geology, ALICE SPRINGS 1:250 000 Sheet area (Langworthy). Because of the structural and metamorphic complexity of the crystalline rocks of the *ALICE SPRINGS* 1:250 000 Sheet area (Fig. M3), the stratigraphic relationships of the metamorphic rock formations and complexes are poorly known. However, using certain rather tenuous correlation criteria (similarity of rock-type, metamorphic grade, and structural style) and superposition criteria (overprinting

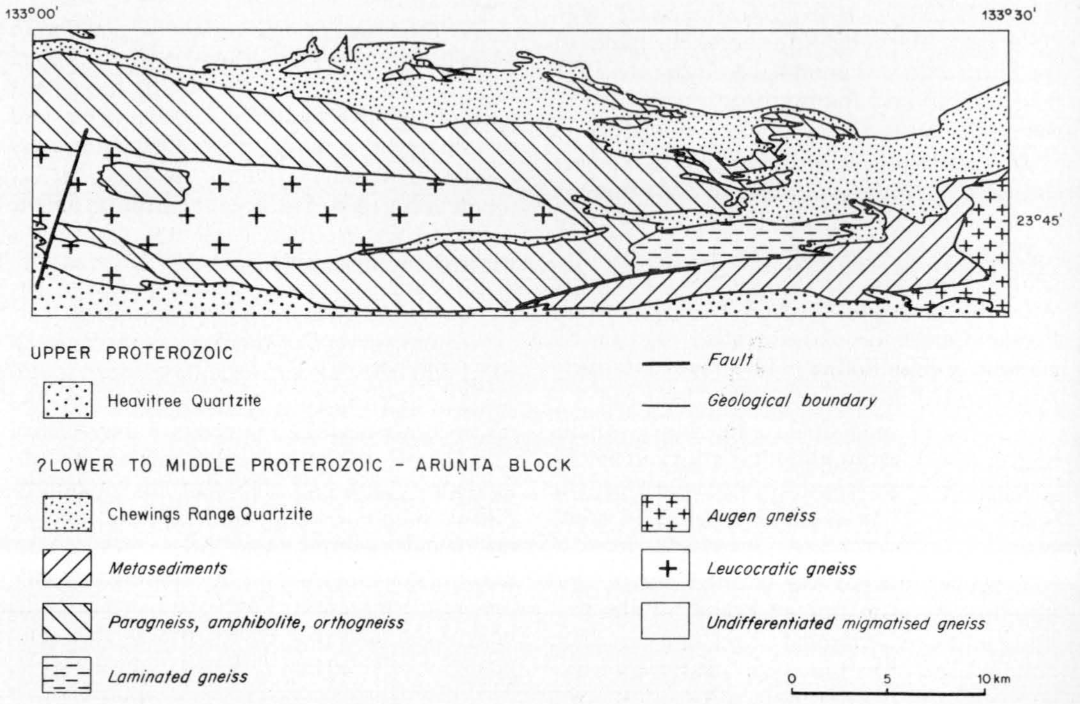


Figure M4 Preliminary sketch map of southern part of basement rocks of MACDONNELL RANGES 1:100 000 Sheet area

of metamorphic facies, sedimentary maturity, assumptions of chemical evolutions, and observed stratigraphic superposition), the formations have been arranged into a schematic rock-relation diagram (Fig. M5 and Table M1). The formations have then been grouped into eight regional categories:

1. The oldest and most extensive division is the Strangways Metamorphic Complex, whose composition indicates marked immaturity of the original sediments. Basal formations consisting of interlayered felsic granulite, mafic granulite (e.g., pCsy, pCsp, and pCso), and cordierite-bearing granulite (e.g., pCsr) are unconformably overlain by the Cadney Gneiss (pCsc), a thick sequence of calc-silicate rocks, sillimanite gneiss, and marble. Isotopic ages of the granulites are about 1800 m.y.

The Complex is bounded to the north by the West Bore Retrograde Zone, an extensive area of retrograde granulite and amphibolite of unknown stratigraphic relationships.

2. The Harts Range Group (e.g., pChe, pCha, pChi, pChb) and correlatives of several of its constituents (e.g., pCx, pCk, pCt) consist of metamorphic rocks whose composition indicates a rather greater degree of sedimentary maturity than that of the Strangways Metamorphic Complex, together with subordinate amounts of metavolcanics and rocks derived from immature sediments. The group is typically metamorphosed to the amphibolite facies with an isotopic age of about 1700 m.y., but granulite facies assemblages occur locally.

The rocks of the Strangways Metamorphic Complex and the Harts Range Group constitute the Ultralanama and Ambalindum Blocks, two major fault-bounded structural subdivisions of the Arunta Block (Fig. M6).

3. The rocks that crop out southwest of the Strangways Metamorphic Complex constitute the Ankala, Narbib, and Wigley Fault Blocks, and may be lithological correlatives of the Harts Range Group. They consist of structurally complex metapelitic gneiss and schist of amphibolite grade, which were migmatized about 1200-1000 m.y. ago.

4. Possibly the youngest stratigraphic division is the sequence in the Alice Valley (e.g., Pac, Pas), which shows the greatest degree of sedimentary maturity in the area. The basal formations of the sequence consist of metapelite and metasandstone, and are overlain by the Chewings Range Quartzite, a recrystallized orthoquartzite. The sedimentary pile is intruded by granite and acid porphyry, and is typically metamorphosed to middle amphibolite facies.

5. Small bodies of metamorphosed granite or anatectic granite (e.g., pCgn, pCgt, pCgo, Pgt) probably have a common age of about 1700-1600 m.y.; a large plutonic complex of diorite-tonalite-granite of similar age has been mapped in the Giles Creek Synform, in the southeastern part of the Arunta Block.

6. Relatively unmetamorphosed igneous rocks (e.g., pCsw, pCgg, Pgg, Pds) have a variety of ages (about 1400 to 1000 m.y.) and compositions, and intrude the metamorphic rocks.

In addition to the above categories, two types of retrograde schist zones have been recognized:

7. The first type belongs to the amphibolite facies, contains kyanite and staurolite, and is probably the result of a retrograde metamorphic event earlier than that which produced the second type.

8. The second probably formed in the Late Palaeozoic, during the Alice Springs Orogeny, and is typically of greenschist to low amphibolite facies.

Two different metamorphic facies series, indicative of a paired metamorphic belt, have been distinguished in the southeasternmost part of the Arunta Block: the rocks in the southwestern part of the White Range Nappe are of low-pressure type, and are characterized by andalusite, cordierite, and anthophyllite; the rocks to the east, in the Giles Creek Synform, are of intermediate-pressure type, characterized by hydrogrossular and hornblende. The paired metamorphic belt, together with the presence of the large igneous body of dioritic composition in the Giles Creek Synform, suggests the presence during mid-Proterozoic time of a west-dipping subduction zone, possibly intracratonic in character.

A suite of intrusive rocks, the Mordor Complex (Pm, Fig. M4), is located 65 km northeast of Alice Springs, in the southeastern part of the *LAUGHLEN* 1:100 000 Sheet area. It is roughly equant, measures 6 km

TABLE M1. Formations of the basement rocks of the ALICE SPRINGS 1:250 000 Sheet area

Pz . . . Palaeozoic
P . . . Proterozoic
pC . . . Precambrian

1 . . . arranged in alphabetical order
2 . . . arranged in order of age, oldest unit at bottom
3 . . . unassigned and unnamed miscellaneous rock units

Name	Map Symbol	Rock
	Pzd	Deformed zone
	Pzr	Retrograde zone
Stuart Dyke Swarm	Pds	Dolerite
	Pgb	Gabbro
	Pdw	Metadolerite
	West Bore Retrograde Zone (Prw)	
	Prw_1	Quartzose metasediments, amphibolite
	Prw_2	Calc-silicate, felsic gneiss, quartzite
	Prw_3	Garnet-muscovite-biotite gneiss
	Prw_4	Retrogressed granulite, cordierite rock
	Prw_5	Layered mafic calc-silicate, felsic gneiss, amphibolite, retrogressed granulite.
Harry Creek Deformed Zone	pCrh	Schist
Southern Cross Schist Zone	pCrs	Schist
Yambah Retrograde Zone	pCry	Kyanite-staurolite-garnet schist
Narbib Deformed Zone	pCrn	Mylonite, pseudotachylyte
	Intrusive Rock Units	
Mudtank Carbonatite	Pzt	Zircon-apatite-magnetite-carbonate rock
Mordor Complex	Pm	Phlogopite peridotite, pyroxenite, shonkinite, monzonite, syenite.
	Ppy	Pyroxenite
	Proterozoic Gneissic Granites[1]	
Alice Springs Granite	Pga	Granite
Atnarpa Igneous Complex	Pgt	Diorite, tonalite, granite
Gumtree Granite	Pgg	Granitic gneiss
	Widley Block	
Old Hamilton Downs Gneiss	Pwg	Granitic gneiss
	Pwm	Migmatite
	pCwl	Layered gneiss, amphibolite
Flint Spring Gneiss	pCwe	Porphyroblastic gneiss, layered gneiss, amphibolite
Forster Gneiss	pCwf	Garnet-biotite gneiss, amphibolite
Colyer Gneiss	pCwc	Garnet-bearing felsic gneiss, layered gneiss, amphibolite
Ten Mile Bore Gneiss	pCwt	Layered gneiss, amphibolite, porphyroblastic gneiss
	pCwv	Garnet gneiss
Bond Springs Gneiss	pCwb	Felsic gneiss
Charles River Gneiss	pCwh	Garnet-biotite gneiss, amphibolite
	pCws	Hornblende gneiss
Redbank Deformed Zone	pCwr	Deformed gneiss
	Sequence in the Alice Valley (Alice Springs Block)	
Runutjirba Gneiss	Par	Felsic gneiss
Burt Bluff Gneiss	Pab	Augen and porphyroblastic gneiss
Chewings Range Quartzite	Pac	Quartzite
Simpsons Gap Metamorphics	Pas	Metapelite and metasandstone

Precambrian Granitic Units [1]

	pCg	Granite
Anamarra Orthogneiss	pCga	Homogeneous granitic gneiss
Georgina Gap Granite	pCgg	Porphyroblastic feldspar gneiss
Mulga Creek Gneiss	pCgm	Muscovite-biotite granitic gneiss
Jennings Granitic Gneiss	pCgn	Biotite granitic gneiss
Oolbra Orthogneiss	pCgo	Porphyroblastic feldspar-biotite schistose gneiss
Trephina Granite	pCgt	Biotite granitic gneiss

Unclassified Precambrian Rock Units

	pC [3]	Biotite gneiss, amphibolite, leucocratic biotite gneiss, felsic gneiss
Ankala Gneiss	pCa	Leucocratic biotite gneiss, calc-silicate, amphibolite
Cement Dam Gneiss	pCc	Porphyroblastic gneiss
	pCf	Amphibolite, felsic gneiss, biotite gneiss
Harry Anorthositic Gabbro	pCh	Anorthositic gabbro
Sliding Rockhole Metamorphics	pCi	Hornblende gneiss, garnet-biotite gneiss, leucocratic gneiss
Cavenagh Metamorphics	pCk	Tonalitic gneiss, flaggy quartzite, marble
Mt Laughlen Quartzite	pCl	Quartzite, muscovite schist
Narbib Gneiss	pCn	Felsic and mafic granulites
Oonagalabi Gneiss	pCo	Felsic gneiss, mafic granulite, amphibolite
Randal Peak Metamorphics	pCr	Leucocratic biotite gneiss, amphibolite, muscovite-biotite schist
Tommys Gap Metamorphics	pCt	Layered hornblende gneiss, quartzite, amphibolite, calc-silicate, marble
Ultralanama Felsic Granulite	pCu	Felsic granulite
Sadadeen Range Gneiss	pCpd	Augen gneiss
Teppa Hill Metamorphics	pCpt	Quartzose gneiss, amphibolite, meta-quartzite
Perta Hill Metamorphics	pCpp	Calc-silicate rock
Emily Gap Schist	pCpe	Biotite schist
Jessie Gap Gneiss	pCpj	Granitic gneiss
	pCpb	Biotite-quartz-feldspar gneiss
	pCv	Hornblende-biotite-microcline granitic gneiss
	pCx	Quartz granitic gneiss, amphibolite
	pCz	Biotite schist

Harts Range Group [2]

Brady Gneiss	pChb	Garnet-muscovite-biotite-plagioclase-quartz gneiss, minor sillimanite
Irindina Gneiss	pChl	Garnet-biotite-plagioclase-quartz gneiss, muscovite schist, minor sillimanite
Naringa Calcareous Member	pChn	Flaggy biotite quartzite, calc-silicate, marble
Mt Riddoch Amphibolite	pChr	Amphibolite
Bruna Gneiss	pCha	Porphyroblastic felsic gneiss
Entia Gneiss	$pChe_1$	Felsic gneiss, muscovite-biotite gneiss, minor hornblende, sillimanite, garnet
	$pChe_2$	Muscovite-biotite granitic gneiss, mafic calc-silicate rock, marble, amphibolite

Strangways Metamorphic Complex [2]

Wuluma Granite	pCsw	Granite
Ingula Migmatite Complex	pCsi	Migmatite and granitoid
Cadney Gneiss	$pCsc_1$	Calc-silicate, marble
	$pCsc_2$	Calc-silicate, felsic granulite, cordierite-sillimanite gneiss
Anuma Schist	pCss	Kyanite schist, staurolite schist
Erontonga Granulite	pCsr	Pelitic granulite
Yambah Granulite	pCsy	Interlayered felsic, mafic, and cordierite felsic granulite, cordierite quartzite
	pCsj	Sapphirine-cummingtonite-spinel-gedrite (anthophyllite)-phlogopite rocks
Mt Pfitzner Granulites	pCsp	Interlayered felsic gneiss and mafic granulite
Ongeva Granulite	pCso	Interlayered felsic and mafic granulites
Adla Gneiss	pCsa	Retrogressed felsic and mafic granulites
	pCsm	Garnet felsic granulite, mafic granulite
Enbra Mafic Granulite	pCse	Mafic granulite, small lenses of felsic granulite

across, and is surrounded by leucocratic gneiss and amphibolite of the Jennings Granitic Gneiss (pCgn, Fig. M4). The Complex is a suite of highly fractionated igneous rocks ranging from phlogopite peridotite through pyroxenite, shonkinite, melamonzite, and monzonite, to syenite. The syenite is a coarse-grained homogeneous rock occupying the western half of the complex. It is intruded by the basic differentiates, which occupy the eastern half, and are themselves intruded by numerous ultrabasic plug-like bodies up to 200 m across, and by pegmatite dykes. The ultrabasic plugs consist essentially of interstitial barium-rich orthoclase, olivine (Fo_{75}), diopsidic augite, bronzite, phlogopite, calcite, apatite, and iron oxides. The more fractionated rocks contain interstitial microcline, and, with decreasing basicity, sodic plagioclase. As a whole, the Complex is low in silica and sodium, but enriched in aluminium, calcium, magnesium, potassium (up to 7.2 per cent), barium (up to 1.5 per cent), rubidium, and strontium (up to 0.6 per cent). It has a high K/Na ratio, a low K/Rb ratio (110-280), and a low Mg/Fe ratio. Thirteen whole-rock samples lie on a Rb-Sr isochron which gives an age of 1230 $\pm$ 100 m.y., and indicates a high initial $^{87}Sr/^{86}Sr$ ratio (0.711 $\pm$ 0.001).

The differentiates of the Mordor Complex are chemically similar to the high-potassium rocks of the Leucite Hills in Wyoming, the volcanics of the Bufumbira province of Uganda and the Roman province of Italy, the kimberlites of Basutoland, and the leucitites of Western Australia. Q-mode factor analysis of the rocks from the Mordor Complex and from the other provinces confirms the chemical similarity of the Mordor ultrabasic rocks to micaceous kimberlites. However, the Mordor ultrabasic rocks are unlike kimberlites in that they contain no pyrope, jadeitic diopside, chrome spinel, or high-magnesium olivine; neither are they porphyritic, brecciated, or tuffaceous; and they contain no ultrabasic autoliths. The parent magma of the Mordor Complex probably came from much the same source as that envisaged for kimberlites, but, instead of being explosively extruded, it intruded to a fairly high level in the crust, and then remained there among hot metamorphic rocks long enough for differentiation to take place.

Miscellaneous. Neither niobium nor rare earths were detected in analyses of four samples of vein carbonate from the Hillsoak Bore (dolomite) and Tommys Gap (calcite) areas, and so the rocks are probably not carbonatites. One sample of retrogressively metamorphosed ultrabasic igneous rock, from 1 km north of Tommys Gap, at the western end of the Giles Creek Synform, contains 0.6 per cent Cr.

ALCOOTA 1:250 000 Sheet area (Shaw, Warren)

The First Editions of the *ALCOOTA* 1:250 000 Geological Sheet and Explanatory Notes were issued. The report 'Geology of the Alcoota 1:250 000 Sheet area' was completed and submitted for editing; it is planned to include it with the Explanatory Notes in microfiche form.

NAPPERBY 1:250 000 Sheet Area and environs

No progress was made on the *AILERON* and *DENISON* 1:100 000 Sheets during the year. The report on the geology of the *REYNOLDS RANGE*, *TEA TREE*, *MOUNT PEAKE*, and *AILERON* 1:100 000 Sheet areas is still in preparation, and will be expanded to include the *DENISON* 1:100 000 Sheet area, the remainder of the *MOUNT PEAKE* 1:250 000 Sheet area, and the Precambrian rocks of the *MOUNT SOLITAIRE* and *LANDER RIVER* 1:250 000 Sheet areas.

REYNOLDS RANGE and TEA TREE 1:100 000 Sheet areas (Stewart, Offe). A transition in regional metamorphic grade, from greenschist to low-granulite facies, in rocks of pelitic composition in the southeastern part of the Reynolds Range was mapped and sampled during 1975. Differences in major-element abundances in three retrogressively metamorphosed acid igneous sills from the central and northwestern parts of the Range confirmed the field interpretation that they are three separate intrusions. One of the sills is unusually high in iron ($FeO + Fe_2O_3 = 6.74$ per cent). At the time of writing, Preliminary Editions of the *REYNOLDS RANGE* and *TEA TREE* 1:100 000 Geological Sheets were being printed.

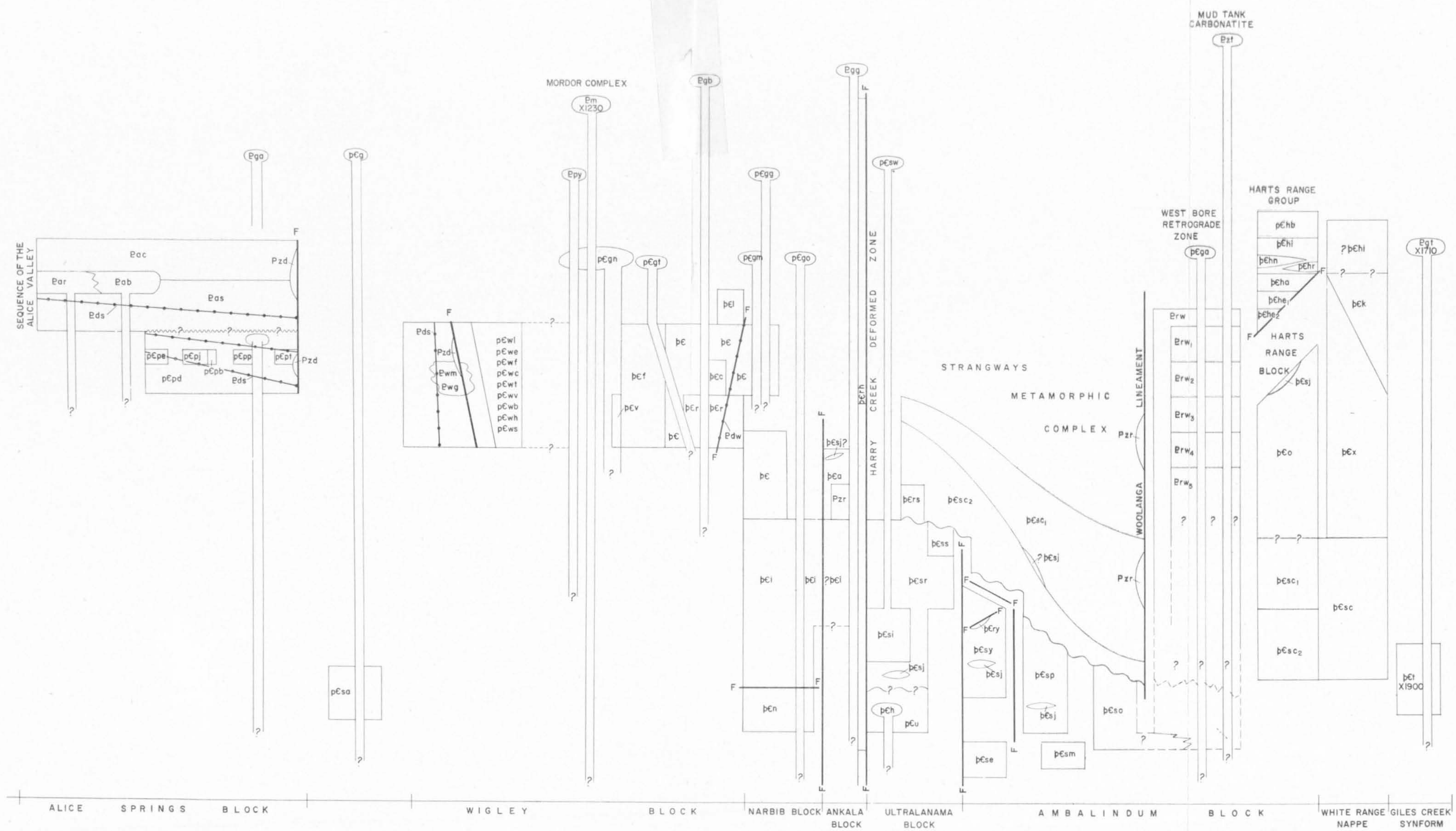


Figure M5 Diagram showing rock relationships, Arunta Block, ALICE SPRINGS 1:250 000 Sheet area (rock units are listed in Table M1)

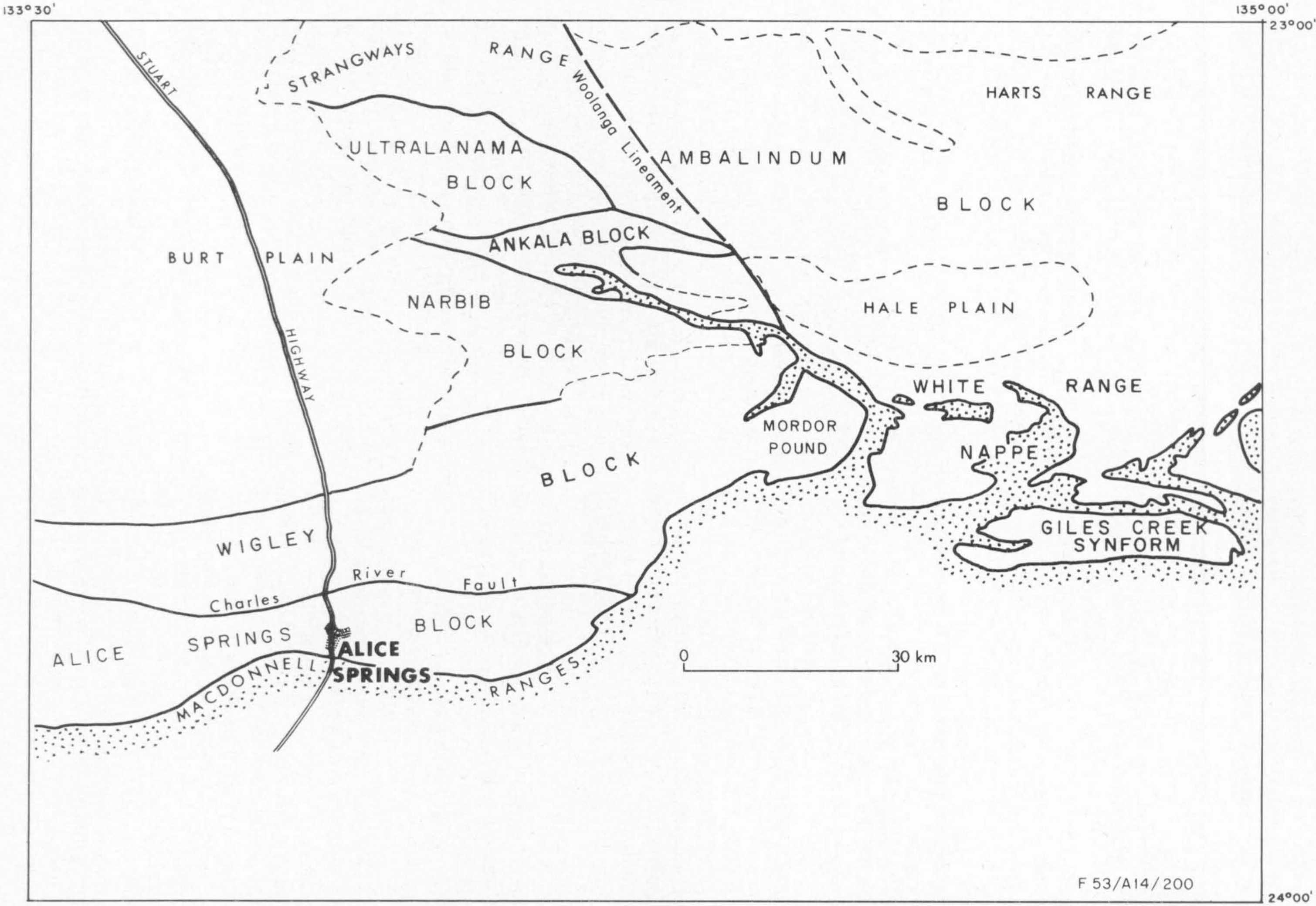


Figure M6 Major structural subdivisions, Arunta Block, ALICE SPRINGS 1:250 000 Sheet area

NAPPERBY 1:100 000 Sheet area (Stewart, Glikson). A geological map, at 1:100 000 scale, of the northeastern part (basement rocks) of the *NAPPERBY* 1:100 000 Sheet area has been drawn.

MOUNT PEAKE 1:250 000 Sheet Area (Offe, Stewart)

Measurement of the type section of the Central Mount Stuart Beds at Central Mount Stewart was completed during 1975, and the Beds are now upgraded and approved as the Central Mount Stuart Formation. A distinctive quartzite at the base of the Formation, in the eastern part of the Sheet area, has been named the Amesbury Quartzite Member. Samples of efflorescent salt on exposures of basal clayey sandstone of the Central Mount Stuart Formation were analysed by X-ray diffraction, and were found to consist of halite (NaCl), thenardite (Na_2SO_4), hexahydrite ($MgSO_4.6H_2O$), and kieserite ($MgSO_4.H_2O$). Two samples of phosphate minerals, in joints in amphibolite and in vein quartz in the Sheet area, were identified as leucophosphite ($K_2Fe_4(PO_4)_4(OH)_2.9H_2O$) and variscite ($AlPO_4.2H_2O$), respectively.

The Preliminary Edition of the *MOUNT PEAKE* 1:250 000 Geological Sheet was printed and distributed, and the map is being prepared for First Edition. The first draft of the Explanatory Notes has been written. The Preliminary Edition of the *MOUNT PEAKE* 1:100 000 Sheet was issued in 1973.

MOUNT THEO 1:250 000 Sheet Area (Stewart)

The Explanatory Notes and Preliminary Edition of the Geological Sheet were edited for First Edition by the Map Editing Group, and the map is being fair drawn.

MOUNT SOLITAIRE and LANDER RIVER 1:250 000 Sheet areas (Offe)

Rocks of the Arunta Block in the southern parts of these two Sheet areas were mapped by helicopter during the 1975 mapping of the Wiso Basin by the Sedimentary Section; they crop out south of a line extending from the northwestern corner of the *MOUNT SOLITAIRE* Sheet area to the southeastern corner of the *LANDER RIVER* Sheet area. The western area contains tightly-folded coarsely-recrystallized metaquartzite, ferruginized metasandstone, and black slate, which are lithologically equivalent to the Mount Charles Beds of the Tanami Complex farther west. In the central and eastern parts of the area, porphyritic granite intrudes mica schist and migmatized gneiss, and is itself intruded by even-grained granite. Pelitic and arenitic hornfelses crop out around a dolerite mass. The rocks in general are similar to those in both the Arunta Block to the south and the Tanami Complex to the west. Northwest-trending ridges of silicified brecciated vein quartz are prominent throughout the area, and are probably fault fillings.

Small amounts of gold in Waldron's Hill Gold Prospect, in the Lander River Sheet area, appear to be confined to a shear zone in hornfels and dolerite. An ironstone outcrop showing boxworks, possibly after chalcopyrite, was sampled.

Geophysical studies (Shaw)

Shaw and W. Anfiloff (Geophysical Branch) continued their study of the gravity anomalies in the Arunta, and submitted a paper—'An interpretation of the tectonics of central Australia in terms of the gravity anomaly pattern, with implications for its lower crustal structure'—for publication in the BMR Journal.

A joint study with the Geophysical Branch was begun on the relation between remanent magnetism, magnetic susceptibility, specific gravity, and radioactivity of migmatites, granites, and related rocks, and the degree of granitization in an area, as well as the relation between these properties and those of other rocks, such as norite and hypersthene dacite. Physical measurements on about 100 samples collected during previous field seasons in the *ALICE SPRINGS* and *HERMANNSBURG* 1:250 000 Sheet areas were statistically compared with rock type. About 200 specimens from the *MOUNT LIEBIG* Sheet area and the adjoining *MOUNT RENNIE* Sheet area to the west were collected during 1975, thin-sectioned, examined, and submitted for determination of the physical properties listed above. Magnetic minerals were separated from 40 samples preparatory to X-ray diffraction analysis. A draft report on the geological aspects of the study was prepared and passed on to the Geophysical Branch. When complete, the report will include a solid geographical map of the *MOUNT LIEBIG* and *MOUNT RENNIE* Sheet areas, based on a new interpretation of the existing aeromagnetic maps, using the results of the current study.

Further information on the project is given in the Annual Summary of the Geophysical Branch.

Isotopic dating (Black, Stewart)

A paper entitled 'Rubidium-strontium dates and extraneous argon in the Arltunga Nappe Complex, Northern Territory' by R. L. Armstrong (University of British Columbia) and Stewart was published in the Journal of the Geological Society of Australia. Black continued sampling the Arunta Block for isotopic dating during the 1975 season; results so far obtained are presented in the report for the Geochronological Laboratory.

Miscellaneous Activities

First Australian Geological Convention. Members of the group attended the First Australian Geological Convention in Adelaide in May, 1975, and presented the following papers (* denotes speaker):

1. 'Towards a stratigraphy of the Arunta Block', by Shaw and Stewart*;
2. 'Tectonics of central Australia', by Shaw* and Anfiloff (Geophysical Branch);
3. 'The Ringwood evaporite deposit—a classical barred-basin marine evaporite in the Proterozoic of the Amadeus Basin', by Stewart;
4. 'The Mordor Complex, a potassic intermediate to ultrabasic intrusion with kimberlitic affinities, central Australia', by Langworthy* and Black; and
5. 'A metamorphosed regolith from the Arunta Block, central Australia', by Warren.

The group then participated in a combined field trip through the Musgrave and Arunta Blocks with officers from the Geological Survey of South Australia and members of the staff and students from the Department of Geology, University of Adelaide. The trip provided a valuable opportunity for the exchange of geological information and ideas on these two related areas.

International Geological Congress, 1976. Stewart, Offe, Langworthy, and Warren wrote contributions for the guidebook to Excursion 47C of the 1976 International Geological Congress, and made a 'dry run' of the excursion with R. G. Dodson (Excursion Leader) during the 1975 field season.

Circum-Pacific Map Project. Warren and Doutch (Sedimentary Section) prepared an abbreviated bibliography of major references to Australian geology and mineral deposits for the Circum-Pacific Map Project.

Training courses. Offe attended a 1½-day Departmental course on Automatic Data Processing, and Stewart attended a 10-day course on the same topic and a 10-day course at the Australian Mineral Foundation on 'Structural Geology and Mineral Exploration'. Stewart also attended a Departmental training course on Man Management from 27 to 31 October.

PINE CREEK GEOSYNCLINE

Darwin Office, by C. E. Pritchard

STAFF: to 25.12.74, C. E. Prichard, P. G. Smart, P. G. Stuart-Smith, P. H. Fuchs. After Cyclone Tracy, C. E. Prichard, P. H. Fuchs, P. R. Lachlan

Until Christmas, 1974, the Darwin Group continued to function normally. The administrative section provided support for field parties, stores were accepted back into store at the end of the field season, and vehicles were examined, and parts required to prepare them for the next season were listed. The Alligator Rivers Geological Party commenced examination and compilation of the season's results, and the drafting of their maps continued. Manton Seismic Station operated, and time signals continued to be supplied to the ABC.

As a result of Cyclone Tracy on Christmas Day, 1974, Manton Seismic Station ceased operating, the Wood Street office lost the roof from the rear half of the building, and all staff had housing problems. Through evacuation, staff was reduced to less than half, and included no geophysicist, senior clerk, storeman, or mechanic. The remaining staff recovered almost all technical records and reference material, and the major part of the administrative records. Fortunately the stores building had remained weatherproof, and

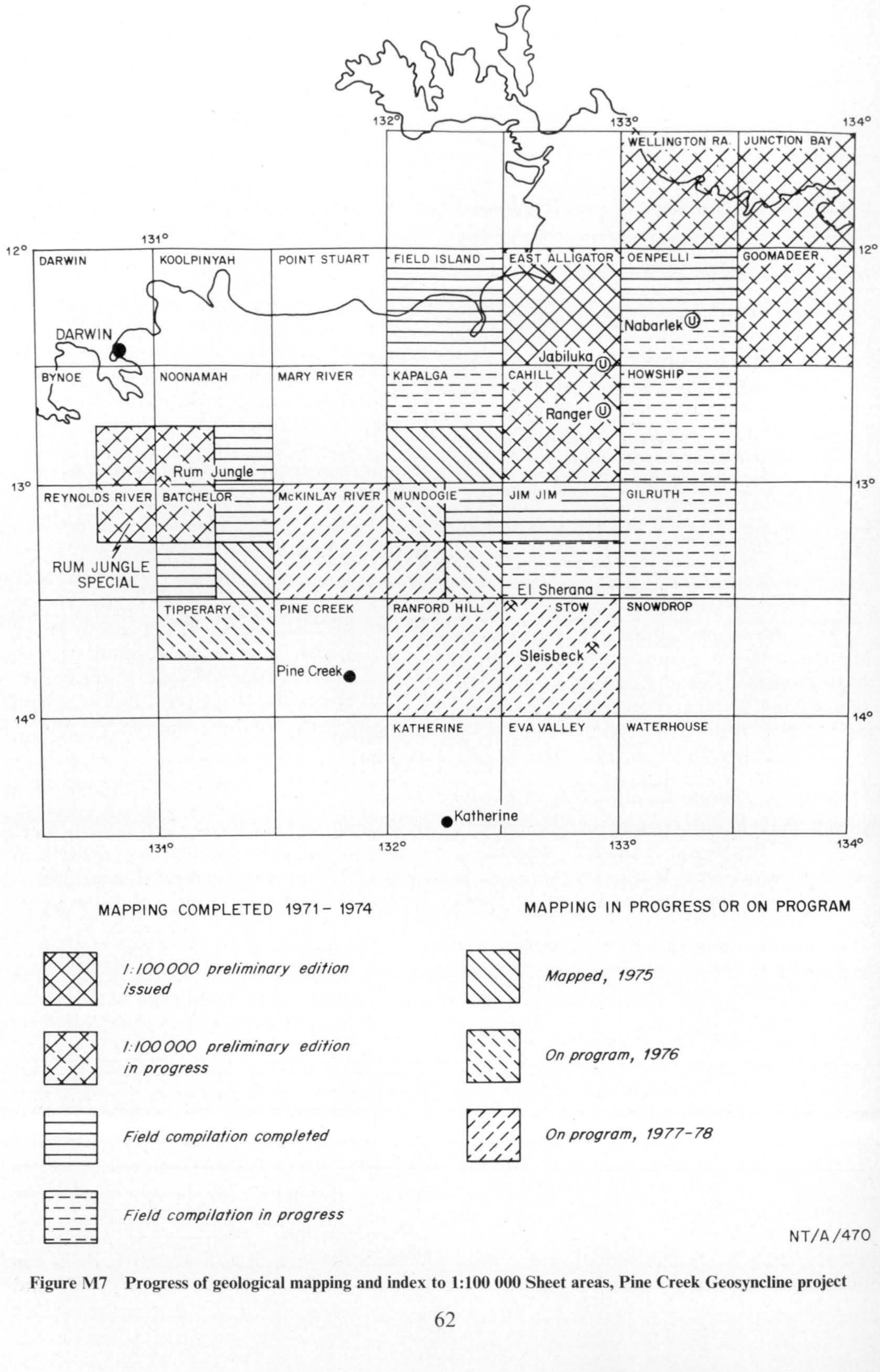


Figure M7 Progress of geological mapping and index to 1:100 000 Sheet areas, Pine Creek Geosyncline project

provided storage against the weather for salvaged material.

Since January, 1975, those remaining of the Darwin Group have concentrated on maintaining a presence in Darwin. The Wood Street office has been re-roofed and secured. Power and telephone are connected. Maps are again available for sale, and limited reference facilities are available. Manton Seismic Station resumed recording early in February. The store is functioning, and the workshop repaired field and other vehicles before and throughout the field season.

The services provided by the office have been used by the Department, the Bureau field parties operating in the area, visiting officers, and the public.

It is expected that the Darwin Office will be functioning normally next year, and will be providing all the services and facilities to the public, and will provide the support and assistance to Bureau operations in the area, that it provided before Cyclone Tracy.

Alligator Rivers Project, by R. S. Needham

STAFF: R. S. Needham, P. G. Smart (seconded to Canberra Technical College from 20.6.75), P. G. Stuart-Smith

The objectives of this project are:

(1) to gain a better understanding of the geology of the Alligator Rivers area, which had previously been mapped only at broad reconnaissance scale;
(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 and South Alligator River valley uranium fields; and
(4) to publish eleven 1:100 000-scale geological maps of the area, and a second edition of the *ALLIGATOR RIVER* 1:250 000 Sheet.

Mapping commenced in 1971. Progress reports have been presented annually as BMR Records. A Bulletin synthesizing the geology of the Alligator Rivers uranium field will be written during 1976.

Nearly all the metamorphic rocks of the area are equivalents of the Lower Proterozoic units recognized in the South Alligator River valley area by Walpole et al., and are not Archaean in age as was previously thought. They are predominantly of amphibolite grade, and include the 'Koolpin Formation Equivalent', which is host to the uranium mineralization.

The future program will be directed to a reassessment of the remainder of the Pine Creek Geosyncline and its mineralization, and especially to establish rock relationships between the Alligator Rivers, South Alligator River valley, and Rum Jungle uranium fields.

Progress of mapping and map production, and projected field programs to 1978, are shown in Figure M7.

Between June and October 1975, a combined program of geological traversing, geophysical electrical and magnetic traversing, and scout and shallow stratigraphic drilling was carried out in the southern part of the *KAPALGA* 1:100 000 Sheet area. Some areas mapped in previous years were revisited, mainly in the *JIM JIM* Sheet area.

KAPALGA 1:100 000 Sheet area. By and large, the geology of the southeast sector of the *KAPALGA* Sheet area, as shown in the *ALLIGATOR RIVER* 1:250 000 Sheet, remains unchanged by the recent mapping. Mount Partridge Formation forms the nose of a north-plunging anticline in the extreme southeast of the area, in the vicinity of Spring Peak (Fig. M8a). The oldest rocks exposed in the anticline are medium-grained feldspathic quartz sandstone and coarse conglomerate, equated with unit 'Plp_1' of the *MUNDOGIE* Sheet area (Needham et al., BMR Record 1975/31). These are unconformably overlain by coarse arkose, equated with 'Plp_2', whose base is marked by up to 20 m of conglomerate. This is in turn overlain with apparent conformity by interbedded phyllite and coarse arkose equated with 'Plp_3'.

A broad north-plunging syncline of massive chert-banded hematitic siltstone of the Koolpin Formation lies to the northwest of the Spring Peak Anticline between the West Alligator and South Alligator Rivers. Prominent arcuate ridges of siltstone marking the limbs of the syncline, and a few outcrops of dolerite, are the only exposures between the two rivers in the southern half of the Sheet

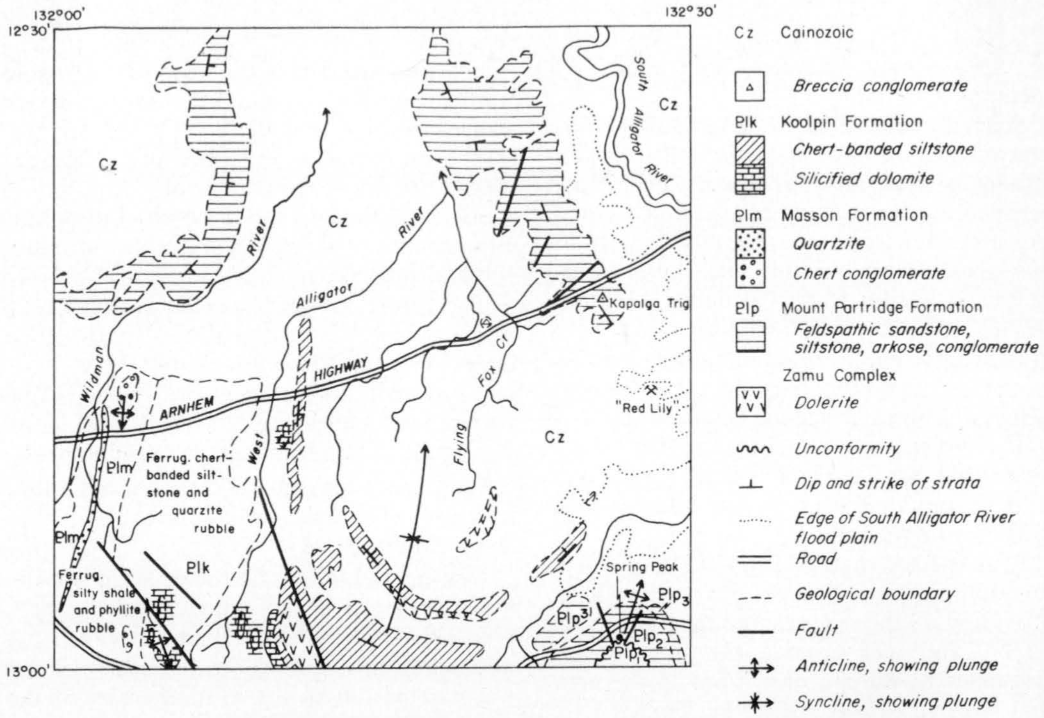


Figure M8a Location and surface geology, KAPALGA 1:100 000 Sheet area

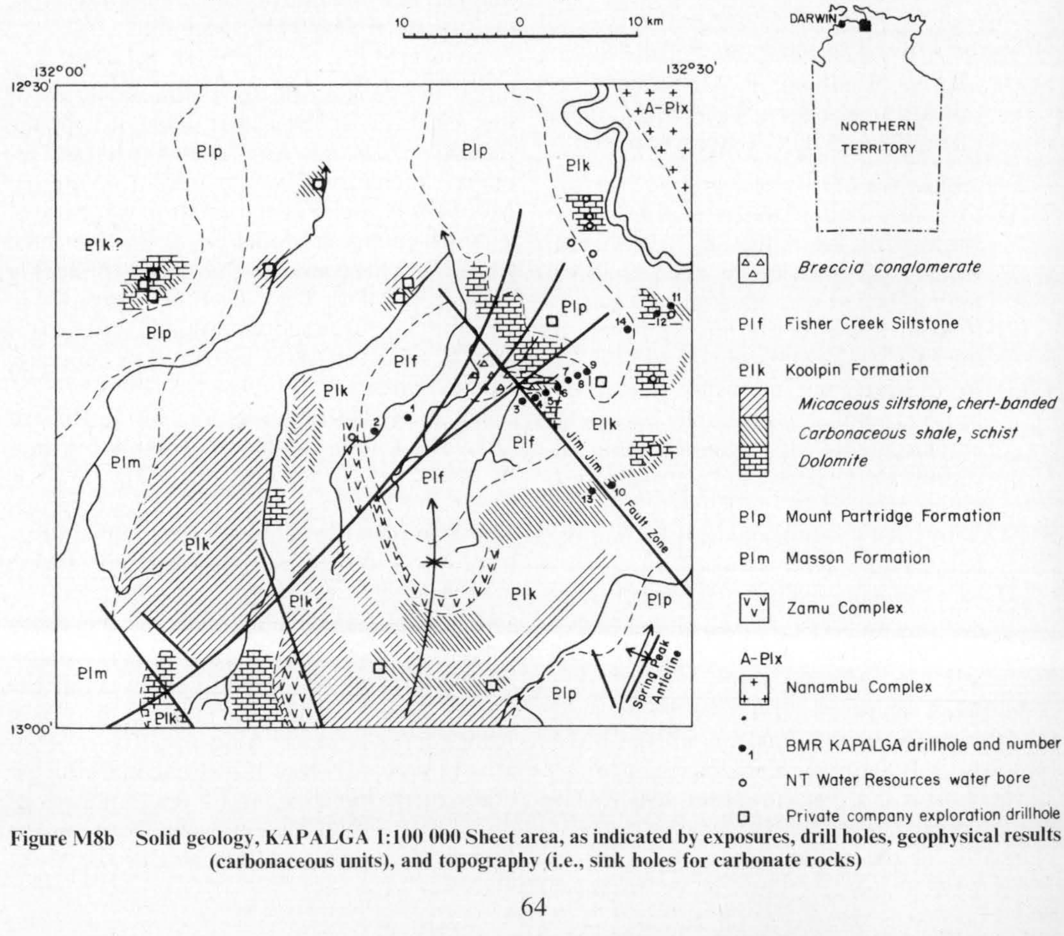


Figure M8b Solid geology, KAPALGA 1:100 000 Sheet area, as indicated by exposures, drill holes, geophysical results (carbonaceous units), and topography (i.e., sink holes for carbonate rocks)

area. Chert predominates over siltstone in some areas near the southern edge of the area. Carbonaceous shale has been intersected in exploration-company drill holes between the chert-banded siltstone ridges. Subophitic coarse dark-grey dolerite of the Zamu Complex forms concordant sill-like bodies, up to 3 km wide in outcrop, within the Koolpin Formation.

An isolated small hill of breccia-conglomerate, unique to the area, and composed of angular fragments of phyllite up to 10 cm across in a ferruginous coarse sandstone matrix, occurs 1 km north of the Arnhem Highway, 2.5 km west of Flying Fox Creek. Its age is obscure; the similarity between the fragments and the phyllite intersected in BMR drill-holes Kapalga 3 and 4, about 4 km to the southeast, suggests that it is derived from reworking of lower Proterozoic phyllite and sandstone, and hence is the youngest consolidated rock in the Kapalga Sheet area.

West of the West Alligator River, in the southwestern sector of the Sheet area, the geology has been largely reinterpreted through the current work. Extensive areas of silicified dolomite crop out near the southern margin of the Sheet area, and are equated with similar rocks to the south, which were mapped as Koolpin Formation by earlier workers. The dolomite lies at or near the base of the formation, which is predominantly siltstone containing numerous bands and nodules of chert. To the west, the dolomite is succeeded by siltstone, followed by shale with chert conglomerate, and minor quartzite, all of which are tentatively equated with the Masson Formation, but the stratigraphic relation between the two formations in this area cannot be determined because of sparse outcrop.

Several northwest-trending faults transect the southern half of the *KAPALGA* Sheet area. The Jim Jim Fault displaces carbonaceous schist of the Koolpin Formation below the Cainozoic cover, and other parallel faults between the Wildman and West Alligator Rivers displace outcrops of the Koolpin Formation dolomite and the Zamu Complex. A major northeast-trending fault is interpreted as extending from Kapalga Trig, southwest through the *KAPALGA* Sheet area, and linking up with the Grove Hill Crossflexure (Walpole et al., 1968, BMR Bull. 82, p. 152).

Transient electromagnetic (TEM) and magnetic surveys were made over an area of about 300 km^2, mainly in the southeast sector of the *KAPALGA* Sheet area. More detailed results are given in the Geophysical Branch Summary of Activities. The objective was to trace conductive carbonaceous shale below the Cainozoic sediments, which cover about 98 per cent of the area. Carbonaceous shale is known at Anglo American's 'Red Lily Prospect' and in several areas drilled by BHP in the northern half of the Sheet area, but the stratigraphic relation between these occurrences is unknown. They may represent two different units, one below and one above the Mount Partridge Formation, or they may both be Koolpin Formation unconformably overlying the Mount Partridge Formation.

A zone of narrow conductors was traced north from the Red Lily Prospect to the Arnhem Highway, thence southwest to the Jim Jim Fault Zone (Fig. M8b). Beyond the fault, the trend of a broad anomaly several kilometres wide parallels that of exposures of Koolpin Formation farther south. Similar broad anomalies were detected between the Koolpin formation ridges south of Flying Fox Creek, where Noranda had intersected carbonaceous shale by drilling. The change in character of the anomalies across the Jim Jim Fault Zone suggests that narrow, probably steeply (east?)-dipping carbonaceous shale units to the east of the fault zone are faulted against thicker or less steeply north-dipping carbonaceous units west of the fault zone.

The carbonaceous phyllite intersected in BMR Kapalga 6 was not detected geophysically, probably because of the thick (about 50 m) Cainozoic cover, the narrow intersection (about 15 m true thickness), and extensive but sporadic weathering of the carbonaceous material.

The objectives of *drilling* in the *KAPALGA* Sheet area were:

(1) to obtain fresh core samples for metamorphic-grade studies west of the Nanambu Complex;

(2) to compare the sequence on either side of the ridge of Mount Partridge

Formation, to the north of Kapalga Trig;

(3) to test selected conducting targets detected during the geophysical survey.

Two rotary holes were drilled in the central part of the *KAPALGA* Sheet area in late 1974; twelve were drilled in 1975, four of which tested geophysical targets (Fig. M8b). A program to drill 40 holes during 1975 was not achieved, mainly owing to the thickness and unconsolidated nature of the Cainozoic cover. It is planned to complete the proposed drilling during 1976.

The sequence west of the ridge of Mount Partridge Formation is arkose and sandstone (Mount Partridge Formation) overlain by about 1000 m of blue mudstone, shale, siltstone, and minor sandstone, overlain by about 600 m of dolomite and interbedded schist, carbonaceous phyllite, and phyllite (all Koolpin Formation), overlain by phyllite with minor silty shale and sandstone bands (Fisher Creek Siltstone?).

Great difficulty was experienced in drilling between Kapalga Trig and the South Alligator River flood plain owing to layers of unconsolidated coarse river gravel within the Cainozoic sediments. Only one hole was completed successfully, intersecting dolomite and minor weathered carbonaceous shale, which suggests a similarity between at least part of the sequence east of the ridge and that west of the ridge.

Information from NT Water Resources Branch and exploration company drilling has been collated, along with BMR drilling, on the interpretative solid geology map (Fig. M8b).

JIM JIM, MUNDOGIE, CAHILL 1:100 000 Sheet areas. The northwestern sector of the *JIM JIM* Sheet area was extensively re-examined, and minor checks were made in the northeastern sector of the *MUNDOGIE* Sheet area. New road cuttings along the Arnhem Highway in the *CAHILL* Sheet area were also mapped.

Detailed mapping by Noranda (Aust.) Ltd in the northwestern sector of the *JIM JIM* Sheet area revealed extensive creek exposures which had not been recorded during the recent BMR work. Numerous exposures of crenulated phyllite and quartz-muscovite schist, arkose, and sandstone were found. The phyllite and schist are tightly folded about axes plunging 30°-60° southeast, concordant with a major southeast-plunging syncline which dominates the structure of the area. The arkose and sandstone show folds plunging to both the southeast and northwest, and probably represent an upfaulted block of Mount Partridge Formation truncating the northeast limb of the syncline containing the phyllite and schist. The phyllite and schist contain rare bedded chert, but lack the massive chert bands characteristic of the Koolpin Formation, and are therefore correlated with the 'Koolpin Formation Equivalent' which is known to be the host rock to uranium mineralization in the Alligator Rivers uranium field.

Medium-grained dark-grey ophitic to porphyritic dolerite intrudes the Lower Proterozoic metasediments in the northwestern sector of the *JIM JIM* Sheet area as two narrow steeply dipping dykes about 3.5 km long and approximately parallel to the southeast-trending fold axes of the area. The dolerite is therefore younger than the Zamu Complex, because the latter forms sills folded with the enclosing rocks.

Folds were re-examined in parts of the Mount Partridge Formation in the Mount Partridge Range because large-scale folding, which had not been recorded during earlier ground traverses, had been seen from the air during helicopter traverses in 1974. The feldspathic quartzite in the main ridge is folded into broad similar folds, and local overturning is indicated by cross-stratification. However, the nature of folding is such that the sequence is not repeated regionally, and therefore the repetition of similar rock types throughout the range is a stratigraphic, rather than a structural, feature. The pelitic members of the formation lack metamorphic index minerals, and their textures had been considered to indicate greenschist-facies grade. However, a higher metamorphic grade is indicated by a new discovery of lenses of amphibole schist intercalated with quartzite. The composition of the other sediments was apparently such that the mineral assemblages remained unchanged during the metamorphism. Compositional banding within the less competent phyllite and metasiltstone members of the formation is generally concordant with the bedding of the adjacent quartzite members, but the younger metamorphic foliations generally show strong chevron folding.

Koolpin Formation exposures in the central eastern part of the *MUNDOGIE* Sheet area, where extensive areas of carbonaceous shale had been revealed by company drilling, were visited. Chert bands in the Koolpin Formation decrease markedly near the southern end of the Mount Partridge Range, probably indicating an eastwards facies change into the 'Koolpin Formation Equivalent' exposed east of the range. The disposition of the Mount Partridge Formation and the Koolpin Formation in this area suggests an unconformable relation between them.

The Stag Creek Volcanics in the Mundogie Inlier were revisited. In the western part of the inlier, altered basalt and agglomerate are overlain by about 30 m of tuffaceous siltstone and tuff, which is in turn overlain unconformably by the basal conglomerate of the Mount Partridge Formation.

Nanambu Complex and 'Koolpin Formation Equivalent' are exposed in four road cuttings along the Arnhem Highway in the northwestern sector of the *CAHILL* Sheet area. Cuttings 5.8 and 6.8 km east of the South Alligator River bridge expose weathered granular and augen gneiss, foliated coarse leucogneiss, biotite schist, amphibolite, and fresh foliated biotite granite of the Nanambu Complex with foliation dipping 75° to the west. Cuttings 12 and 18.7 km east of the bridge expose parts of the western and eastern limbs, respectively, of the 'Woolwonga Syncline' in which 'Koolpin Formation Equivalent' is folded into Nanambu Complex. Rock types are massive to bedded chert, garnet-mica-quartz schist, and carbonaceous schist, together with weathering products of schistose rocks. In the 12 km cutting, the 'Koolpin Formation Equivalent' is overlain to the west by mottled coarse conglomerate and pebbly coarse clayey sandstone of unknown age.

Rum Jungle and western Pine Creek Geosyncline

STAFF: I. H. Crick, K. Johnson (transferred to Department of the Environment, July, 1975), J. A. Ingram (resigned May, 1975).

Following many years of subsurface geochemical, geophysical, and petrological studies in the Rum Jungle district, geological mapping was recommenced in 1972 to produce a Second Edition, at 1:100 000 scale, of the Rum Jungle District Special Sheet. Field work over the area covered by the Second Edition was completed during 1974, and mapping was then extended into the adjoining areas of the *BATCHELOR*, and the southeastern part of *NOONAMAH*, 1:100 000 Sheet areas (Fig. M9). During 1975, field work was concentrated in the southeastern quadrant of the *BATCHELOR* Sheet area, and it is planned to complete the mapping of this area during 1976, together with the northern half of *TIPPERARY* 1:100 000 Sheet area, and then publish a combined Batchelor-Tipperary Sheet.

The objectives of the project are:

(1) To help to re-assess and gain a better understanding of the geological evolution of the Pine Creek Geosyncline;

(2) To use this information to re-assess the potential for uranium, base-metal, and other mineralization in the Pine Creek Geosyncline; to gain a greater understanding of the controls and distribution of this mineralization; and especially to determine the relation between the mineralization in the Rum Jungle, South Alligator River valley, and Alligator Rivers uranium fields;

(3) To publish 1:100 000-scale geological maps of selected areas.

Rum Jungle District 1:100 000 Special Sheet, by K. Johnson. The revised Rum Jungle District Special Sheet is bounded by longitudes 130°50'E and 131°15'E, and by latitudes 12°45'S and 13°15'S. Field compilations at 1:25 000 scale have been completed, and drawing of the 1:100 000 Preliminary Edition is well advanced.

The geology of the Sheet area has been described previously (Johnson, BMR Record 1974/41). The principal refinements which have been made to the First Edition Sheet as a result of the new work are:

(1) The Rum Jungle Complex and Waterhouse Complex have been subdivided in detail, confirming Rhodes's (1965, BMR Report 89) subdivision of part of the Rum Jungle Complex.

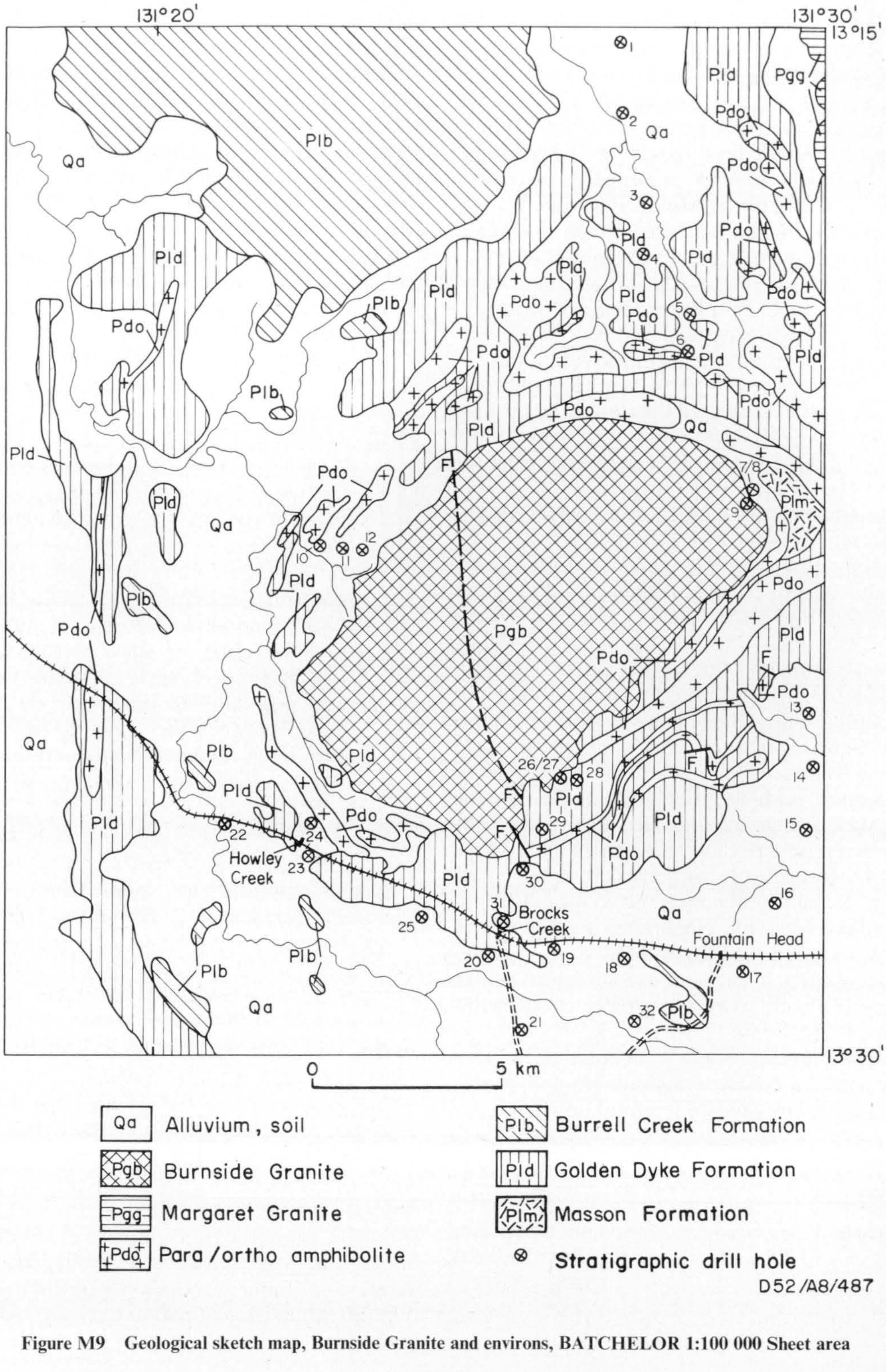


Figure M9 Geological sketch map, Burnside Granite and environs, BATCHELOR 1:100 000 Sheet area

(2) The lower Proterozoic units have been subdivided in more detail.
(3) The structural relation between the basement and cover has been reinterpreted: Rather than superimposed folding being responsible for the doming of the basement and cover rocks (Williams, 1963, Territory Enterprises Pty Ltd, unpubl. report), a diapiric intrusion of granite into the basement rocks is believed to have caused the domed structures (Stephansson & Johnson, Precambrian Res., in press).

Batchelor 1:100 000 Sheet area, by I. H. Crick. During 1975, mapping was carried out mostly in the southeastern quadrant of the Sheet area. The rocks in the area consist mainly of the Burnside Granite surrounded by the Golden Dyke Formation and interlayered amphibolites (Fig. M9). The Burnside Granite is a homogenous fine to medium-grained biotite adamellite. The Golden Dyke Formation comprises mainly carbonaceous pyritic shale with interbeds of dolomite near the base and chert and siliceous shale towards the top. These grade upwards into siltstone and greywacke of the overlying Burrell Creek Formation. Pink and grey silty to knotted schists, some containing chiastolite, crop out near the granite. Gold, copper, and bismuth lodes are contained in the Golden Dyke Formation around the Burnside Granite, but mining ceased many years ago.

Most of the new data remain to be assessed, but the principal results to date are:
1. The Burnside Granite is surrounded by a typical rim syncline;
2. The 'Mount Minza-type Ironstone' marker bed within the Golden Dyke Formation can be traced into the area from Rum Jungle;
3. Previously unidentified outcrops of probable Masson Formation occur adjacent to the eastern part of the Burnside Granite;
4. Rocks which were previously mapped as hornfels within the western rim syncline consist of chert of the Golden Dyke Formation and silicified 'tombstone greywacke' of the Burrell Creek Formation;
5. Limestone, previously mapped with Golden Dyke Formation near Howley Creek Siding, passes along strike into coarsely crystalline dolomite.

During 1975, 32 holes were drilled around the Burnside Granite (Fig. M9) in order to obtain samples of bedrock in areas of no outcrop, and fresh samples of Golden Dyke Formation in areas of deep weathering.

Cores from the Burrell Creek Formation (Nos. 1, 13, 14, 17, 18, 19, 21, 22, and 32) consist mainly of quartz-biotite arenite, in places feldspathic; graded bedding was observed in No. 32. In the transition zone between the Golden Dyke and Burrell Creek Formations (Nos. 2, 11, and 15), bands of phyllite are intercalated with shale, siltstone, and quartz arenite. Most cores from the Golden Dyke Formation (Nos. 3, 4, 5, 16, 20, 25, 26, 27, and 29) consist of dark-grey shale, some with graphite-rich bands, and most contain disseminated or vein pyrite; one core (5) contains disseminated chalcopyrite. Holes 10 and 24 intersected coarse-grained dolomite, and cores 6, 21, and 31 consist mostly of chert. Hole 8 passed through medium-grained amphibolite and intercalated bands of dark micaceous lutite and quartzite into a quartzite which possibly belongs to the Masson Formation.

THE GRANITES-TANAMI PROJECT, BY D. H. BLAKE

STAFF: D. H. Blake, I. M. Hodgson (part time); P. C. Muhling (GSWA, part time)

The purpose of this project was the systematic geological mapping, at a scale of 1:250 000, of The Granites-Tanami region, an area of mainly Precambrian rocks, which lies between the Kimberley region, to the northwest, and the Arunta Block, to the southeast. Before the present survey began in 1971, little was known of the stratigraphy and geological setting of the area. Field work was carried out in 1971, 1972, and 1973, and involved the mapping of four 1:250 000 Sheet areas in the Northern Territory—*BIRRINDUDU*, *TANAMI*, *THE GRANITES*, and *HIGHLAND ROCKS*—and parts of four similar Sheet areas in Western Australia—*BILLILUNA*, *LUCAS*, *STANSMORE*, and *WEBB*. The First Edition maps of the Northern Territory sheets and *WEBB*, and Second Editions of *BILLILUNA* and *STANSMORE*, together with their Explanatory Notes, are either in press or ready for publication, and a Report (174) on the northeastern part of the area has been released.

Work on a Bulletin describing the geology of the region, and on the 1:500 000 map which will accompany it, continued during the year, and is scheduled for completion by March, 1976. A paper on the geochronology and related aspects of the acid volcanics, associated granites, and other Proterozoic rocks of The Granites-Tanami region, prepared in conjunction with R. W. Page and M. W. Mahon, was completed, and has been accepted for publication in the BMR Journal. Papers on the Precambrian stratigraphy, correlations, and the economic potential of the region were presented at the BMR Symposium, Canberra, and at the First Australian Geological Convention of the Geological Society of Australia at Adelaide in May, 1975.

ANTRIM PLATEAU VOLCANICS PROJECT, BY R. J. BULTITUDE

Bultitude devoted most of the year to projects associated with the work of the Rabaul Volcanological Observatory and the Duchess Party.

Maps to accompany the Record on the geology and petrology of the Antrim Plateau Volcanics were largely completed during the year, and a paper dealing with the volcanics was written for the G. A. M. Taylor Memorial Volume.

VICTORIA RIVER BASIN PROJECT, BY K. A. PLUMB

All work on this regional mapping project was completed early in 1975. The party leader, I. P. Sweet, was on extended leave for most of the year. All nine 1:250 000 geological maps and Explanatory Notes have been published, the last two during 1974. Three Reports describing different parts of the region have also been published, the last (167) being issued during 1975.

A Bulletin summarizing the geology of the whole region has been edited, and is awaiting drafting of text figures. The accompanying geological map at 1:500 000 scale has been fair-drawn, and is with the printer.

KIMBERLEY REGION, BY K. A. PLUMB

STAFF: K. A. Plumb, G. M. Derrick.

1:500 000-scale geological maps of the West Kimberley and the North Kimberley (previously called Kimberley Basin) regions were edited and revised for coloured editions during the year, and fair-drawing is well advanced. Reports describing the geology of the *LANSDOWNE* (152) and *LENNARD RIVER* (153) 1:250 000 Sheet areas were published during the year; the first of the group (Charnley, 154) was published during 1974.

Plumb is organizing an excursion to the Kimberley Region (44C) for the International Geological Congress. Planning of the excursion and writing of the excursion guide-book are in progress.

McARTHUR BASIN, BY K. A. PLUMB

A comprehensive synthesis of the geological evolution of the whole McArthur Basin, illustrated by a series of palaeogeographic maps, was presented at the First Geological Convention of the Geological Society of Australia at Adelaide in May, 1975. The paper is now being expanded and revised for eventual publication by BMR. In view of comprehensive new studies planned for the McArthur Basin in the near future, it is proposed to use this synthesis as a replacement for an earlier proposed Bulletin, which was to have described the southern McArthur Basin (Roper River to Queensland Border); the Arnhem Land Bulletin is well advanced and, despite lack of progress during 1975, will still be completed.

A detailed project proposal is being prepared, which outlines a major program of specialist studies of the geological evolution of the McArthur Basin, and of the distribution and genesis of the basin's base-metal deposits. This will be a multi-disciplinary study, involving many fields of earth science, and will continue for many years; it is hoped that field work can commence in 1977.

Extensive pseudomorphs after gypsum and anhydrite have been identified in several formations of the McArthur Group by Dr Marjorie Muir (Imperial College, London) and others, and they add significant new data relevant to the palaeoenvironmental studies of the group.

A discovery during 1974 of Cambrian trilobites within the Arafura Basin succession (unconformably above the McArthur Basin) on Elcho Island, is of considerable importance to regional correlations in northern Australia; the beds had been considered, from isotopic dating of glauconite, to be of Adelaidean age. A paper by Plumb, J. H. Shergold, and M. Z. Stefanski (Water Resources Branch, Darwin) describing the significance of the discovery, has been accepted for publication in the BMR Journal. L. P. Black has sampled the glauconite beds to investigate the cause of the unusual anomalous isotopic age; the usual experience is for glauconite ages to be too young, rather than too old.

The International Geological Congress Excursion to the McArthur Basin (46A), which Plumb was to have led, has been cancelled because of insufficient applicants.

ANTARCTICA

STAFF: R. J. Tingey (full time); R. N. England, A. P. Langworthy, P. E. Pieters, J. W. Sheraton, D. Wyborn (part-time); P. A. Arriens (ANU, full time)

Introduction, by R. J. Tingey

BMR geologists have worked with the Australian National Antarctic Research Expedition (ANARE) since its inception in 1948, and by the late 1960s had completed reconnaissance geological mapping of the exposed rocks in Australian Antarctic Territory; since the mid-1960s emphasis has been on systematic regional mapping at 1:250 000 scale of areas where outcrops are relatively abundant. The major objectives are to contribute to the international scientific investigation of Antarctica, and to assess the mineral potential of Australian Antarctic Territory. BMR makes by far the largest Australian contribution to the international programs supervised by the Geological Working Group of the Scientific Committee on Antarctic Research (SCAR).

Systematic regional geological mapping of the Prince Charles Mountains was started in 1968, and completed in 1974. Nine 1:250 000-scale Preliminary Edition geological maps have been issued, and the remaining four are in press. During the 1974-75 season the annual multidisciplinary ANARE summer expedition embarked upon a major field program in Enderby Land; geological mapping at 1:250 000 scale is a major component of this program, which will last for at least three years.

In the 1974-75 season emphasis was given to glaciology, and to surveying and aerial photography in preparation for future geological field work. Geological mapping had low priority for logistic support, and only two BMR geologists, Pieters and Wyborn, took part. They mapped around trigonometrical stations, and intended to make a wide reconnaissance in preparation for later field work, when geological mapping, by at least four geologists, would have priority for logistics. However, owing to very poor weather at the base camp and the loss of two aircraft, the season was virtually a complete failure, apart from the experience gained by the participants. No aerial photography was obtained, and the geologists visited only nine widely scattered outcrops in eastern Enderby Land. The whole Enderby Land program has been put back by a year, and will re-start in the 1975-76 season when a new base camp will be used.

Tingey, England, Langworthy, Sheraton, and Arriens continued work on data from the Prince Charles Mountains. England and Langworthy completed a Record on their 1974 work in Antarctica, and Arriens presented the results of his Rb-Sr age determination work at the First Australian Geological Convention of the Geological Society of Australia at Adelaide in May, 1975. England continued examination of thin sections of rocks from the Prince Charles Mountains, and compiled a metamorphic map of the area. Sheraton completed chemical analysis for 10 major and 17 minor elements on 200 specimens from the Mawson/Prince Charles Mountains area, and is preparing his results for publication.

Tingey has supervised the drafting of eight 1:250 000-scale Preliminary Edition geological maps of the Southern Prince Charles Mountains, and has extensively revised a Record on the 1973 field work in that area. The Record should soon be submitted for editing, but the proposed Bulletin on the geology of the Prince Charles Mountains has been delayed, pending the results of further geochronological, geochemical, and petrological investigations.

In December, 1974, the Advisory Committee for Antarctic Programs (ACAP) issued its report, and the Minister for Science later issued a related Green Paper entitled 'Towards New Perspectives for Australian Scientific Research in Antarctica'. Tingey prepared comments on this Green Paper on behalf of BMR. A continuing commitment by BMR to Antarctic work is envisaged, and increased University participation in Antarctic Research, as recommended by ACAP, is thought not to conflict with this. ACAP specifically recommended that Antarctic geological programs should be investigated by an expert committee, and the Geological Society of Australia has been invited to form such a committee.

Enderby Land and Macquarie Island, by P. E. Pieters and D. Wyborn

During the 1974-75 season Pieters and Wyborn resumed geological mapping in Enderby Land following the reconnaissance work in 1965 by Trail, McLeod, Cook and Walliss (1967, BMR Report 118). Good-quality vertical aerial photography of Enderby Land does not exist, and mapping was carried out using old trimetrogon photography of variable quality, and base maps compiled from it. As explained previously, field work was restricted, and only a few scattered observations were made. Later in the season Pieters and Wyborn visited outcrops near Mawson, and, during the return voyage from Antarctica, landed at Macquarie Island, and made a few reconnaissance traverses on foot.

Granulite-facies metamorphic rocks, ranging from charnockite through mangerite to enderbite, together with quartz-feldspar gneiss, garnet gneiss, and generally subordinate pyriclasite (mafic granulite) and ultramafic gneiss, were found at nine scattered localities in Enderby Land. However, at one locality (Newman Nunataks) quartz-magnetite rock, containing up to 40 per cent by weight Fe, comprises the uppermost bed of a synform. Many of the more acid rocks are intersected by small biotite pegmatite dykes that contain high-temperature perthite and mineral assemblages that reflect the composition of the host rocks, so the dykes are thought to have been emplaced during the main granulite-facies metamorphism.

Two specimens of biotite pegmatite were submitted to AMDL for K-Ar dating, and gave ages of 580 ± 12 m.y. and 511 ± 10 m.y. These are similar to a Gondwanaland-wide thermal event which is commonly detected by the K-Ar method, and are more likely to reflect this event than the time of emplacement of the dykes.

The youngest rocks seen are weakly metamorphosed dolerite dykes that cut across, and are clearly younger than, the gneiss. Retrograde reactions, such as the conversion of hypersthene to hornblende, and hornblende to biotite, are seen locally in the gneisses, and may be related to the metamorphism of the dolerites. Hypersthene is present in some specimens of the quartz-magnetite rock, and others nearby contain riebeckite and actinolite. Retrograde metamorphism appears to have been confined to discrete small zones, but its controls are not known.

Broad reaction rims around garnets, in thin sections from several localities, are evidence for the prograde reaction:

$$\text{Garnet} + \text{clinopyroxene} \rightarrow \text{orthopyroxene} + \text{plagioclase.}$$

This reaction could proceed as a result of heating at constant pressure, or reduction of pressure at constant temperature, and is thought to have been associated with the original granulite-facies metamorphism.

Macquarie Island consists of two fault-separated volcanic complexes that have been studied in detail by Varne and Rubenach from the University of Tasmania. Pieters and Wyborn mapped a dyke of kaersutite-bearing trachybasalt from near Mount Gwynn.

Unusual potassium-rich alkaline rocks from Mount Bayliss, Prince Charles Mountains, by J. W. Sheraton

Following the discovery of float specimens of altered magnophorite-bearing leucite lava at Mount Bayliss by D. S. Trail in 1961, a mafic dyke that intersects, and is clearly much younger than, the metamorphic basement was mapped there during the 1972-73 field season. Arriens' Rb-Sr geochronological studies show that the metamorphic basement at Mount Bayliss is 2630 m.y. old, and K-Ar age determinations show that the mafic dyke was emplaced about 420 m.y. ago.

The dyke also contains the rare potassium-rich richteritic amphibole, magnophorite, and, like the lava, is particularly rich in TiO_2, K_2O, P_2O_5, Rb, Sr, Zr, and Ba, and poor in

Al_2O_3. It belongs to a rare suite of rocks which are known from only four other localities—Leucite Hills, Wyoming; the West Kimberley area, Western Australia; Montana; and southeastern Spain.

The Mount Bayliss mafic rock has been compared with leucite basalt from Gaussberg, Wilhelm II Land, and with a porphyritic olivine basalt from Manning Massif, in the northern Prince Charles Mountains. (Specimens of the Gaussberg rocks were provided from the collection of Mawson's 1911-12 Australasian Antarctic Expedition by courtesy of the Mawson Institute, University of Adelaide). The Manning Massif rock is chemically distinct from the other two, which have very similar chemical characteristics, although the Gaussberg rock is leucite- and olivine-normative, and the Mount Bayliss ones are quartz-normative.

Basic and alkaline intrusive rocks in the Prince Charles Mountains, by R. J. Tingey

A selection of basic and alkaline intrusive rocks that intersect, and are clearly younger than, the metamorphic basement of the Prince Charles Mountains was dated by the K-Ar method by A. W. Webb, of AMDL. Results are given in Table M2, together with data from other parts of the Australian Antarctic Territory. The range of ages and the variety of methods used restrict the conclusions that can be drawn from these data.

Soviet workers have inferred, from the alnöites at Radok lake, that kimberlitic rocks may be present in the Prince Charles Mountains, but no such rocks have so far been mapped. No carbonatites have been found, and the discovery of kimberlites in this terrain presents formidable practical difficulties.

Table M2. Age determinations of some basic rocks in Eastern Antarctica

Locality	Rock type	Method	Age (m.y.)
Fox Ridge	Alkali basalt dyke	K-Ar pyroxene	504 ± 20
Gaussberg, Wilhelm II Land	Leucite basalt flow	K-Ar whole rock	9.0
Manning Massif	Porphyritic olivine basalt flow	K-Ar whole rock	51.8, 49.1 ± 2.0
Mount Bayliss	Magnophorite-bearing mafic dyke	K-Ar magnophorite	414, 413 ± 10
		K-Ar riebeckite	430 ± 12
Radok Lake	Alnöite sill	K-Ar phlogopite	110 ± 3
Taylor Platform	Tholeiite dyke	K-Ar plagioclase	246 ± 6
Vestfold Hills, Princess Elizabeth Land	Dolerite dykes	Rb-Sr whole rock	1400

(All specimens are from the Prince Charles Mountains, except where otherwise indicated.
Fox Ridge, Manning Massif, Radok Lake, and Taylor Platform are all within the *BEAVER LAKE* 1:250 000 Sheet area.)

GEOLOGICAL INVESTIGATIONS IN QUEENSLAND AND PAPUA NEW GUINEA

Supervising Geologists: D. B. Bow (until January), D. H. Blake (after January)

MOUNT ISA-CLONCURRY PROJECT, BY G. M. DERRICK & R. M. HILL

STAFF: G. M. Derrick, R. M. Hill, B. A. Duff (part time), D. J. Ellis (part time), R. W. Page (part time); I. H. Wilson, T. A. Noon (GSQ); P. J. Goldsworthy (QDM, draftsman)

Derrick returned to BMR from the University of Queensland in January, and Duff left BMR late in 1974 to study at Leeds University. Noon transferred to the Duchess Party in mid-1975.

Introduction

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 struc-

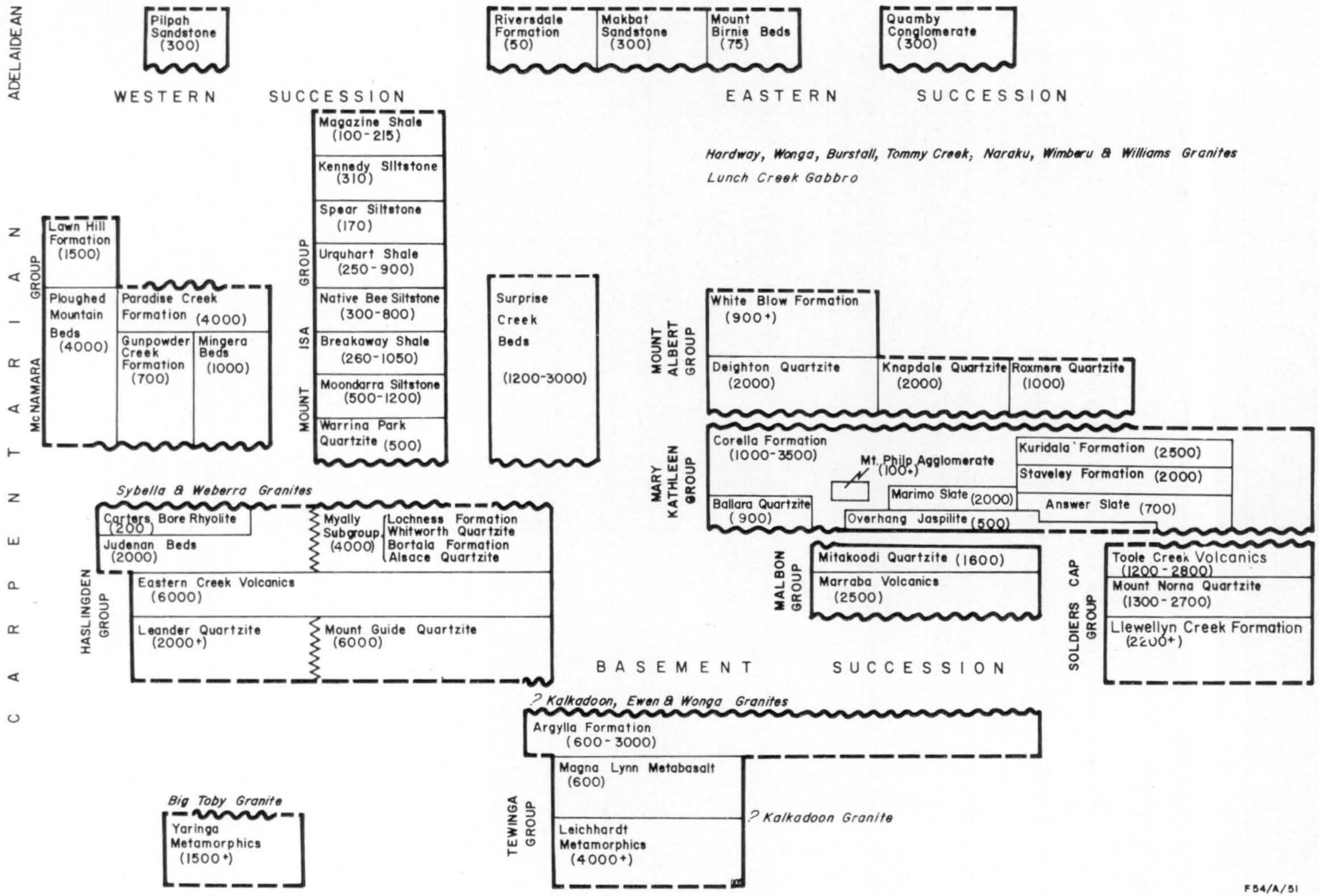


Figure M10 Correlation diagram of Proterozoic stratigraphic units, Mount Isa-Cloncurry region (average thicknesses in metres) ture, and to reconstruct the sedimentary, igneous, and metamorphic history of the region.

Field activities

Derrick and Wilson assisted with photo-interpretation and reconnaissance mapping in the *DUCHESS* 1:100 000 Sheet area, and re-examined certain critical areas in the *MOUNT ISA*, *MARY KATHLEEN*, *MARRABA*, and *QUAMBY* Sheet areas. Hill mapped poorly exposed Precambrian rocks in the northern part of the *CLONCURRY* 1:100 000 Sheet area, and assisted with a geophysical survey designed to map Precambrian basement beneath thin Mesozoic and younger cover.

Rifle Creek area, MARY KATHLEEN 1:100 000 Sheet area

Contacts between possible basement rocks and the overlying Mount Guide Quartzite were re-examined. In the lower part of the sequence, boulder and cobble conglomerate lenses are interbedded with acid spherulitic lavas and/or tuffs. Higher in the sequence the conglomerates are interbedded with arkose, labile feldspathic sandstone, and minor basalt lavas. The sequence containing acid volcanics is referred to the Argylla Formation, and the sequence above the volcanics, to the Mount Guide Quartzite (Fig. M10). The stratigraphic level marking cessation of acid volcanicity can be traced southwards into the *DUCHESS* 1:100 000 Sheet area. The close similarities between the conglomerates in the Argylla Formation and the Mount Guide Quartzite suggest that sedimentation was more or less continuous, and that there was no major time break between the two units.

Dugald River area, QUAMBY 1:100 000 Sheet area

Parts of the Dugald River area were re-examined to elucidate the lithology of, and relation between, the Corella Formation and Knapdale Quartzite (Fig. M10). Near the Lady Clayre mine, 8 km south-southwest of the Dugald River zinc prospect, a sequence of stromatolitic chert and quartzite is faulted against the Knapdale Quartzite; the stromatolitic sequence consists of a 20 cm-thick bed of columnar stromatolites overlain by a 50 cm-thick, stratiform, domed ?biostrome. The columnar stromatolites are parallel to slightly divergent, and are branched; the branches are about 1.5 cm thick, and contain slightly convex laminae which provide useful facing criteria in the complex fold zone adjacent to the faulted contact.

The ?biostromal bed shows fine siliceous laminae and asymmetric doming. The domes are about 1 m in diameter. The bed is overlain by a discontinuous bed of grey shale up to 40 cm thick and a bed of laminated quartzite at least 2 m thick which displays slightly undulatory layering. Brecciated laminated quartzite similar to that in the stromatolite sequence is associated with copper mineralization at Lady Clayre, and there is a possibility that similar cupriferous, siliceous, laminated, and brecciated rocks associated with the Dugald River zinc-bearing shale are equivalents of the stromatolite sequence at Lady Clayre.

Along the western edge of the Knapdale Quartzite a sequence of fine-grained sandstone, siltstone, and black shale, possibly equivalent to the White Blow Formation, appears to overlie the Knapdale Quartzite conformably, and farther west is faulted against grey to black pyrrhotitic shale thought to form part of the upper Corella Formation. The relation between the Corella Formation and the Knapdale Quartzite remains equivocal.

Cloncurry area, CLONCURRY and MARRABA 1:100 000 Sheet areas

Detailed reconnaissance mapping by Hill in the *CLONCURRY* 1:100 000 Sheet area shows that north of the Flinders Highway the Toole Creek Volcanics of the Soldiers Cap Group (Figs M10 and M11) are conformably overlain by a sequence of (in ascending order) banded iron formation, slate, impure feldspathic quartzite, metabasalt, quartzite, laminated calcareous shale, and stromatolitic chert and jaspilite. This entire sequence, previously mapped as the middle unit of the Soldiers Cap Group, appears to be overlain unconformably by calc-silicate breccias of the Corella Formation, and may correlate directly with parts of the Malbon and Mary Kathleen Groups which crop out around the Duck Creek anticline, 20 km southwest of Cloncurry. The Corella Formation rests unconformably on the above sequence of older

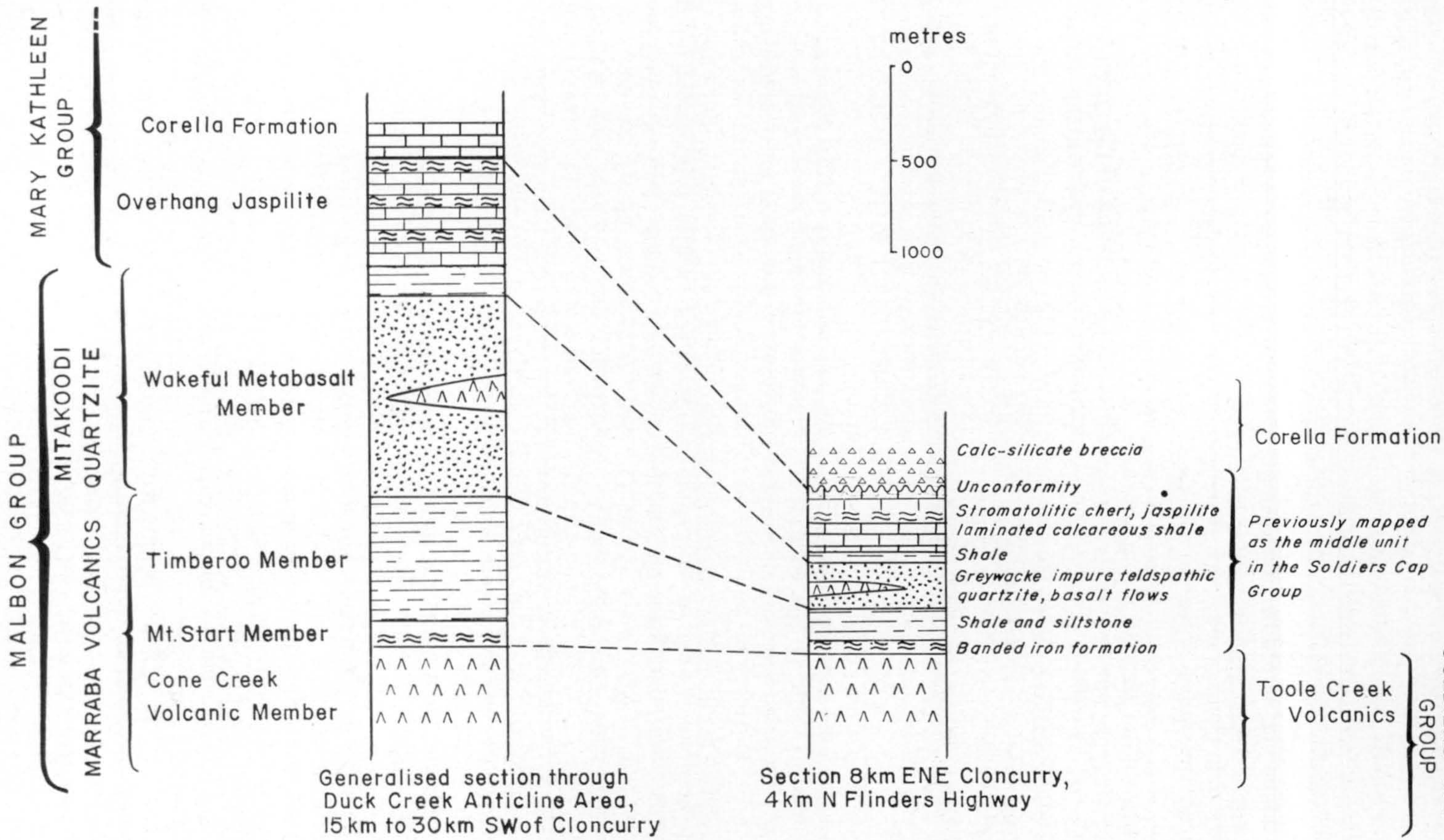


Figure M11 Revised stratigraphic correlations, vicinity of Cloncurry township rocks in the Soldiers Cap/Cloncurry area, but appears to be conformable on the sequence in the Duck Creek anticline.

Aeromagnetic and ground geophysical surveys have located large magnetic and gravity anomalies in the area north of Cloncurry between Ilkley and Fort Constantine homesteads. Geological mapping suggests that these anomalies are due to thick, folded sections of jaspilite and banded iron formation belonging to the sequence described above. The magnetic response of these rocks may be enhanced in the anomalous areas, where they are in the contact aureole of the Naraku Granite.

Office activities

Most activity has been directed towards the preparation of 1:100 000 maps and accompanying reports, of excursion guide books, and of papers and lectures for external presentation.

Maps and reports. The Record describing the geology of the *MOUNT ISA* Sheet area was edited (Hill was the main contributor). The draft of the Record describing the geology of the *PROSPECTOR* Sheet area was written, and editing is in progress (Wilson, Noon, Hill, Derrick, Duff). Work on the preliminary maps and reports on the geology of the *KENNEDY GAP* and *QUAMBY* Sheet areas is in progress; drawing of the *KENNEDY GAP* Preliminary Edition map was undertaken by GSQ and the Queensland Department of Mines; *MARY KATHLEEN* and *MARRABA* 1:100 000 Sheets were edited for First Edition, and the Mary Kathleen Record (1974/90) was issued. Preliminary compilation of data was completed for the *BULLECOURT*, *TEMPLETON*, *YELVERTOFT*, and *WAROONA* 1:100 000 maps (Noon, Wilson, Duff). A contribution was completed for the new Geological Map of Queensland (Wilson, Noon). A report (BMR Record 1975/84) on 1971 diamond drilling was issued, and writing of the 1973 drilling report is in progress (Hill).

Guide books. A guide book was written for the proposed International Geological Congress excursion in the Mount Isa area in 1976 (Wilson, Derrick), following some field checking during July and August, 1975, along the planned excursion route. Wilson contributed to the guide book used at the Geological Society of Australia field conference held in the Mount Isa region during June, 1975.

Papers and lectures. Two papers were presented at the Australian Geological Convention on the Proterozoic, held in Adelaide during May. They were entitled, 'Evolution of Proterozoic topography and the formation of mineralized basins in northwest Queensland' (Derrick, Wilson), and 'Basin and dome deformation in the Mount Isa geosyncline' (Duff, Wilson); both contributions present some preliminary data on the applicability of plate tectonic theory to the evolution of the Proterozoic terrain in northwest Queensland.

Our knowledge of the Precambrian of northwest Queensland is now sufficient to warrant a complete revision of the stratigraphic nomenclature of the region. A paper entitled 'Revision of Stratigraphic Nomenclature in the Precambrian of Northwestern Queensland' (Derrick, Wilson, Hill) is in preparation. It will be submitted to the Queensland Government Mining Journal for publication in several parts.

Geochemistry. Duff completed a geochemical and statistical study of core samples of black shale from a hole drilled in the upper part of the Corella Formation 11 km west-northwest of Mary Kathleen. Geochemical studies of core samples from the Overhang Jaspilite penetrated in DDH 6 (Hill, Duff, Wilson) are at an early stage. An analytical program has been formulated for investigating the jaspilite sedimentary environment.

Geochemical soil and stream sediment sampling near BMR Cloncurry DDH 8, 12 km west-northwest of Mary Kathleen, indicated some zones of anomalous copper mineralization, and a report (BMR Record 1974/182) on this area has been prepared by A. G. Rossiter. Wilson continued investigation of the geochemistry of, and secular geochemical trends in, the Tewinga Group, mainly in the *Prospector* 1:100 000 Sheet area. Derrick assessed the results of about 150 uranium assays from rocks near Mary Kathleen: it is evident that uranium mineralization is part of a metasomatic/hydrothermal event possibly related to emplacement of a rhyolite and microgranite dyke swarm; the uranium may have been derived either from the dyke rocks or from the metasedimentary pile, but probably mainly from the former.

Ellis continued his geochemical study of basic dyke rocks in the region.

Geochronology, palaeomagnetism. R. W. Page carried out detailed investigations of the Rb and Sr isotopic abundances in the Lunch Creek Gabbro and Lakeview dolerite dyke, and is re-examining samples of Mount Isa granitic and volcanic rocks at the Carnegie Institution in Washington, using zircon studies to supplement the existing Rb-Sr results. Further sampling of the Lunch Creek Gabbro and Wonga Granite was undertaken during 1975. The Lunch Creek Gabbro, which intrudes the Corella Formation, appears to be about 1500 m.y. old.

Duff and B. J. J. Embleton (CSIRO) completed an initial palaeomagnetic study of the Eastern Creek Volcanics, Lunch Creek Gabbro, and various dolerite dykes. They suggest that the Lakeview dolerite dyke near Mary Kathleen and dolerite from near the Mount Isa microwave tower were coeval, although the field relations suggest a significant time break between them. A reversal in the magnetic field was recorded in the Lunch Creek Gabbro.

Other activities

Hill attended a departmental course. 'Introduction to A.D.P.', during June, and a course, 'Interpretation of Airborne Magnetic Surveys', at the Australian Mineral Foundation in Adelaide during July.

Technical advice was provided for field visits by delegations from the People's Republic of China in May, and from the International Training Course in Mineral Exploration during September.

DUCHESS PROJECT, BY R. J. BULTITUDE, R. N. ENGLAND & C. M. GARDNER

STAFF: R. J. Bultitude, R. N. England, C. M. Gardner, G. M. Derrick (part time), D. H. Blake (part time); T. A. Noon (GSQ)

Introduction

The aims of the project are to systematically remap the Precambrian rocks in *DUCHESS* and *URANDANGI* 1:250 000 Sheet areas, to produce geological maps at 1:100 000 scale of the areas, and to assess their mineral potential.

During the 8-week field season, the party examined type sections and exposures of rock units in the *CLONCURRY* and *MOUNT ISA* 1:250 000 Sheet areas, and commenced mapping the Precambrian rocks in the *OBAN*, *DUCHESS*, and *MALBON* 1:100 000 Sheet areas to the south (Fig. M12). Outcrops of mainly basement rocks and immediately overlying sequences were examined, and a provisional stratigraphic sequence was set up. Evidence was found for the existence of a major unconformity between a basement complex, consisting of granitic rocks and relatively high-grade metamorphics, and an overlying sequence of lower-grade regionally metamorphosed volcanic and sedimentary rocks.

General geology

The oldest rocks so far found in the area occur as inclusions, some more than 100 m long, in granitic rocks in the northwestern part of the *DUCHESS* 1:100 000 Sheet area. These rocks are now schistose, gneissic, or hornfelsic, and in places are intimately veined by granite to form migmatite complexes. Northwest of Bushy Park they appear to be mainly metamorphosed basic to acid volcanics. Similar rocks elsewhere in the region were previously mapped as Leichhardt Metamorphics.

The granitic rocks of the basement complex, previously mapped as Kalkadoon Granite, are generally coarse-grained, and commonly contain white feldspar phenocrysts. Northwest of Bushy Park they consist mainly of biotite granite and granodiorite containing contaminated dioritic patches, and cut by aplitic veins; pegmatites appear to be rare. The rocks show a steeply dipping foliation trending north to northeast. To the east, in the area around Kurbayia, exposures consist of non-foliated biotite granite and granodiorite, small masses of granite containing pink feldspar phenocrysts up to 10 cm long, coarse muscovite granite, and quartz-pink feldspar-muscovite pegmatite veins: xenoliths less than 1 m across are common, but larger inclusions are rare.

The basement complex is cut by numerous basic dykes, most of which are at least partly schistose, and are now amphibolite or biotite schist metasomatically formed from amphibolite.

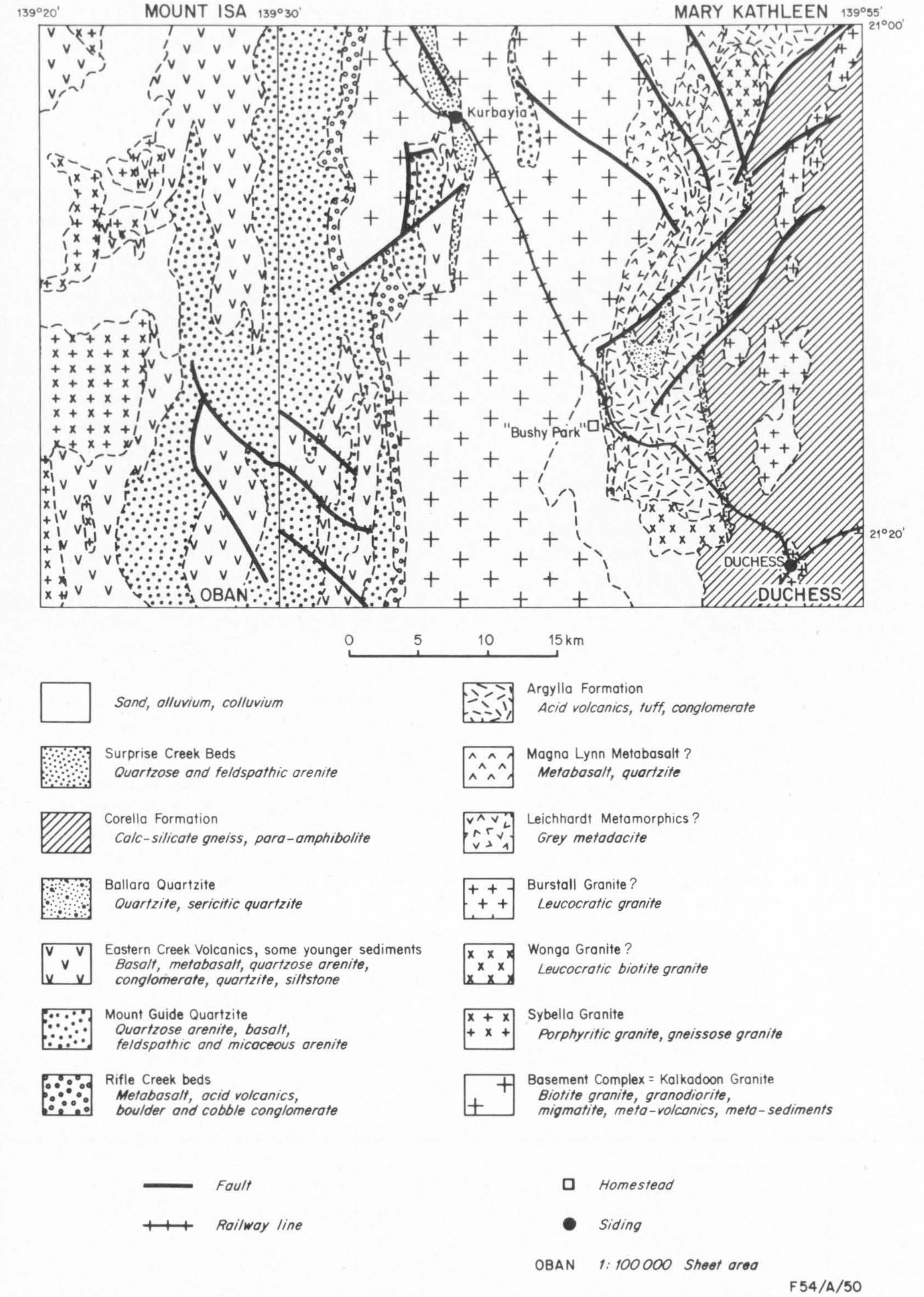


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Figure M12 Geological sketch map of parts of the DUCHESS and OBAN 1:100 000 Sheet areas

It is postulated that, after their formation, the 'Leichhardt Metamorphics' were deeply buried, regionally metamorphosed, and intruded by the granitic rocks. The latter were emplaced at relatively deep levels, and incorporated parts of the country rocks to form the xenolithic, migmatitic, and contaminated granites of the crystalline basement. A thin conglomerate consisting mainly of subangular clasts of vein quartz, found resting directly on crystalline basement about 16 km west-northwest of Bushy Park, is taken to indicate the existence of a major time break between the basement complex and an overlying layered sequence of rocks. During this interval, the area was uplifted and subjected to prolonged subaerial erosion; cover rocks were stripped off, and the crystalline basement was exposed.

The sequence overlying the basal conglomerate consists of regionally metamorphosed (foliated and schistose) basaltic and dacitic lava flows, some possible rhyolitic pyroclastics, and associated thin quartzose and tuffaceous beds and non-quartzose conglomerate. Together these made up the Rifle Creek beds. The basaltic lavas occur locally at or near the base of the sequence, and are possible correlatives of the Magna Lynn Metabasalt mapped to the north, in the *MARY KATHLEEN* 1:100 000 Sheet area. The overlying acid volcanics and associated sediments, which are tentatively correlated with the Argylla Formation, are overlain by a distinctive coarse conglomerate which has been mapped as the basal part of the Mount Guide Quartzite in the adjacent *MARY KATHLEEN* Sheet area. Similar conglomerate is also present locally between layers of acid volcanics lower in the sequence. The sequence shows considerable local variations, and its thickness ranges from more than 1000 m to less than 50 m. These variations may be attributable to deposition on a highly irregular surface.

The upper conglomerate contains subangular to well-rounded pebbles, cobbles, and boulders of quartzite, acid and minor basic volcanics, and granite similar to that of the underlying basement. It is generally schistose, and most clasts are flattened and distorted. Local cross-bedding and graded bedding indicate deposition in water. The matrix, which is quartz-poor, forms more than 50 percent of the rock, and probably has a high volcanic (tuffaceous?) content. The conglomerate may represent a mixture of alluvial fan and volcaniclastic deposits. The large size (up to 1 m) of many of the clasts indicates local derivation.

The Rifle Creek beds are overlain, apparently conformably, by the ridge-forming sandstone of the Mount Guide Quartzite (mapped as the upper unit of the Mount Guide Quartzite in the *MARY KATHLEEN* Sheet area). Some thin basaltic lava flows are present within the unit, mainly near the top. The unit has been regionally metamorphosed, and is somewhat schistose. It is overlain, probably conformably, by Eastern Creek Volcanics, a sequence of regionally metamorphosed basaltic lava flows (ranging from about 20 to 40 m thick) and interlayered, locally thick lenses of quartzose arenite and conglomerate. The lavas, which were probably extruded subaerially, are amygdaloidal, and have scoriaceous and commonly epidotic tops, which locally contain primary and secondary copper minerals. A conglomerate within the unit contains subangular to rounded clasts of porphyritic acid volcanics unlike any known elsewhere in the region.

Northwest of Bushy Park, Eastern Creek Volcanics appear to be overlain unconformably, rather than faulted against, unmetamorphosed sandstones assigned to the Surprise Creek Beds, the youngest Precambrian rocks so far recognized in the northwestern part of the *DUCHESS* Sheet area. The unconformity would appear to represent a period of tectonic activity and regional metamorphism. The Sybella Granite, which intrudes the Eastern Creek Volcanics in the *OBAN* 1:100 000 Sheet area to the west, and a small fluorite-bearing granitic body previously mapped as Kalkadoon Granite northwest of Duchess, may have been emplaced during this period. Gneissic and contaminated dioritic rocks are exposed in the contact zone between the Eastern Creek Volcanics and the Sybella Granite.

Predominantly shale and siltstone sequences, mapped as Mount Isa Group to the north, are exposed in small fault-bounded blocks within the Eastern Creek Volcanics in the *OBAN* Sheet area. These units may be broadly equivalent to the Surprise Creek Beds. Most of the predominantly quartzitic sequence previously mapped as Judenan Beds has been assigned to the Eastern Creek Volcanics, but some is thought to be equivalent to the Mount Isa Group or Mount Guide Quartzite.

Another major tectonic event took place after the deposition of the Surprise Creek Beds. During this period the Surprise Creek Beds and older units were tightly folded and extensively faulted. Most of the folds and faults trend north to north-northeast, and may be intimately related; some beds, such as the calc-silicate rocks of the Corella Formation, readily formed tight major and minor folds, whereas the more competent quartzites and granitic rocks were faulted and fractured. Shearing, brecciation, quartz veining, and probably some retrograde metamorphism took place along many of the fault lines during this period, but no significant regional metamorphism appears to have affected the rocks now exposed. The high-level granitic masses intruding the Corella Formation about 20 km northeast of Duchess may have been emplaced at this time.

Cover rocks exposed to the east of the basement complex have not been examined in as much detail as those to the west. East of Kurbayia granitic rocks of the basement complex are faulted against a sequence of strongly sheared grey 'metadacites', previously mapped as Leichhardt Metamorphics. East of Bushy Park these rocks are intruded by veins and pods of fine to medium-grained leucogranite. The 'metadacites' are faulted against and in places overlain, possibly conformably, by a succession of regionally metamorphosed basaltic lava flows and thin intercalations of quartzite; this succession is tentatively correlated with the Magna Lynn Metabasalt. Both the acid and basic volcanic sequences display a strongly developed north-south foliation. One question still to be resolved, however, is whether there are two different sequences of rocks previously mapped as Leichhardt Metamorphics—an older sequence intruded by the basement granite, and a younger sequence overlying the basement. The metabasalts in the east are overlain, apparently conformably, by a sequence of quartzose sediments, intensely altered quartz-free sediments that are probably tuffaceous, and porphyritic rhyolitic volcanics. This sequence is tentatively correlated with the Argylla Formation. The three mainly volcanic sequences are cut by significantly fewer basic dykes than the adjacent basement complex to the west. The 'Argylla Formation' is overlain, probably unconformably, by the Ballara Quartzite. This formation, which thins southwards, is conformably overlain by calc-silicate gneisses and para-amphibolites of the Corella Formation. About 10 km north of Duchess the Corella Formation has been regionally metamorphosed to amphibolite grade, and intruded by small bodies of biotite granite.

Most of the units previously known in the *MALBON* Sheet area were examined. Several of these were traced southwards from the *MARRABA* Sheet area.

WESTMORELAND PROJECT, BY J. E. MITCHELL, I. P. SWEET & C. M. GARDNER

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

Introduction

The aim of the project was to remap at 1:100 000 scale the Precambrian rocks in the *HEDLEYS CREEK* and *SEIGAL* 1:100 000 Sheet areas (Fig. M13), and to re-assess their mineral potential. These areas are part of the Westmoreland area, which lies between the McArthur Basin in the Northern Territory to the north and the Mount Isa region of northwest Queensland to the south. Field work commenced in 1972, and was completed in 1973. Preliminary Edition maps of the *HEDLEYS CREEK* 1:100 000 Sheet area and *WESTMORELAND* 1:250 000 (Second Edition) are now available, and the Preliminary Edition map of the *SEIGAL* 1:100 000 Sheet area is due to be issued early in 1976.

During the year Mitchell prepared a Record on basement acid volcanic rocks (Cliffdale Volcanics), and Gardner continued her work on the Nicholson Granite Complex. Sweet, who was on leave for most of the year, completed a Report on the regional setting and Precambrian cover rocks. Mitchell spent three months in the field assisting in a regional geochemical survey of the Hedleys Creek and Seigal 1:100 000 Sheet areas, and carried out some checking of the geology.

Summary of geology

Four major tectonic units have been recognized in the Westmoreland area—the basement Murphy Tectonic Ridge, the McArthur Basin to the northwest, and the Lawn Hill Platform and overlying South Nicholson Basin to the southeast.

The Murphy Tectonic Ridge consists of schistose metamorphic rocks (the Murphy Metamorphics), the Nicholson Granite Complex and the Cliffdale Volcanics. The name Nicholson Granite Complex is proposed for units previously known as the Nicholson and Norris Granites, because these granites,

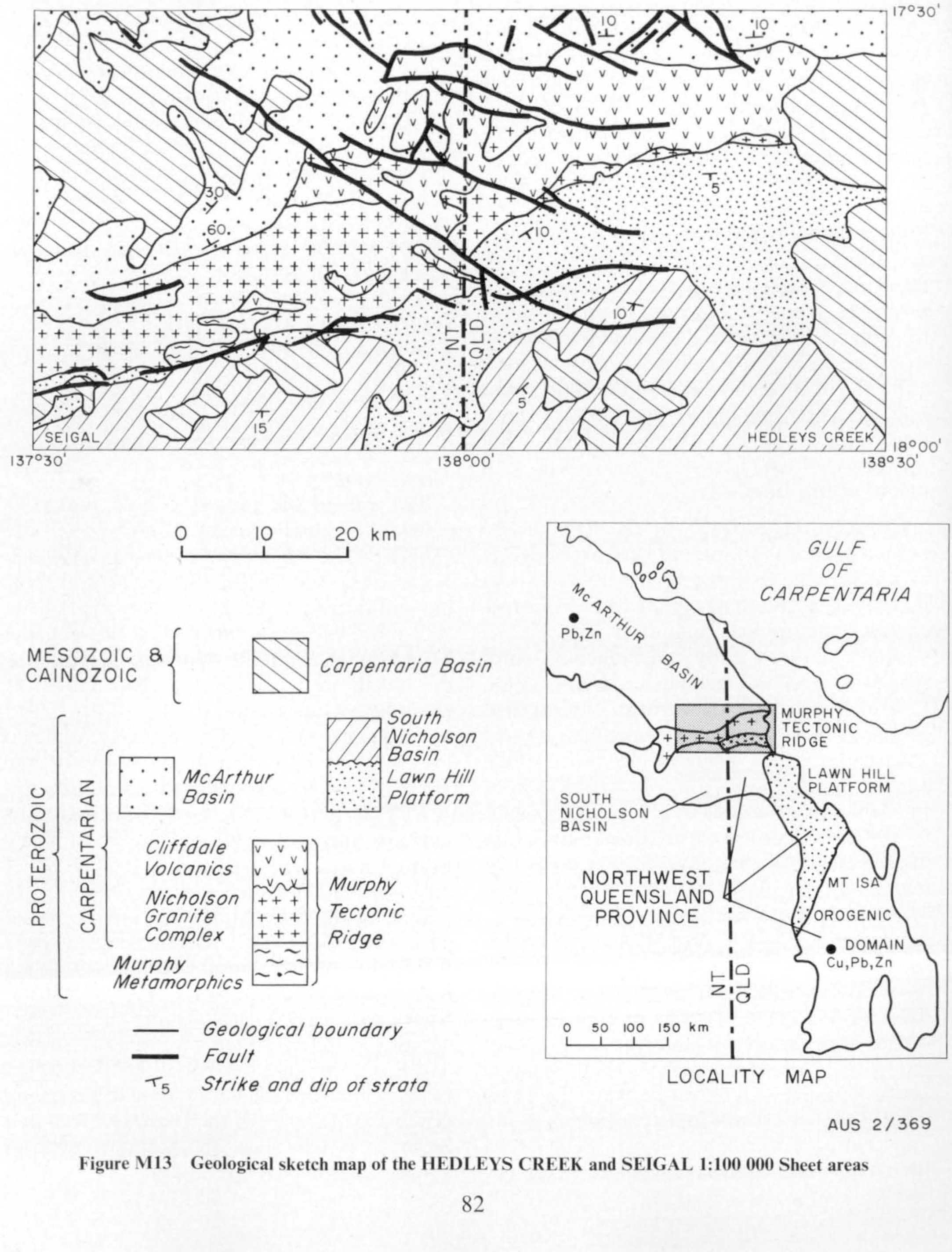

Figure M13 Geological sketch map of the HEDLEYS CREEK and SEIGAL 1:100 000 Sheet areas

together with the Cliffdale Volcanics, lie on a single chemical lineage. Further isotopic dating completed during the year by A. W. Webb substantiates the earlier theory that the Cliffdale Volcanics overlie older granites, and are intruded by younger higher-level granites. The best age for the oldest granite is 1843 $\pm$ 80 m.y., for the youngest granite 1773 $\pm$ 24 m.y., and for the Cliffdale Volcanics 1770 $\pm$ 20 m.y. (Webb, A. W., 1973—Amdel Report AN2/1/0—1814/73).

The Cliffdale Volcanics consist of generally flat-lying to gently dipping dacitic to rhyolitic ignimbrites, flow-banded rhyolitic lavas, and acid tuffs. The volcanics have a maximum measured thickness of about 4000 m; their base is not exposed. They are overlain unconformably by the Westmoreland Conglomerate of the McArthur Basin sequence. Their age of about 1770 m.y. defines the base of the Carpentarian System. The ignimbrites, which make up about half of the Cliffdale Volcanics, contain phenocrysts of quartz, potash feldspar, and sericitized plagioclase, and commonly show well-defined eutaxitic structures. They are generally red-brown or blue-black, depending on the concentration and state of oxidation of opaques in the groundmass, which consists mainly of devitrified glass. The volcanic rocks have not been regionally metamorphosed, but show the effects of thermal metamorphism, such as the development of chlorite, epidote, albite, biotite, and actinolite near intrusive granite contacts. Xenoliths of acid volcanic rocks occur in granite adjacent to steep intrusive contacts, but not in granite near flat-lying contacts. The volcanics are cut by swarms of north and east-trending porphyritic acid dykes and by some dolerite dykes, and they are also intruded by a thick sill of microdiorite. Some of the dykes also intrude adjacent granite.

The only mineralization of present economic importance in the Cliffdale Volcanics is uranium at the Pandanus Creek uranium mine. Minor copper and tin have been mined from small quartz veins near some granite intrusions. Almost all the volcanics were extruded subaerially, and hence are unlikely to have volcanogenic stratiform mineral deposits associated with them.

The McArthur Basin in the area comprises rocks of the Carpentarian Tawallah Group, which is unconformable on the Murphy Tectonic Ridge to the south. The basal unit of the Group is the Westmoreland Conglomerate, a fluvial deposit over 1200 m thick partly derived from the Ridge, which was a land area during much of the Precambrian. The Conglomerate is overlain by 1200 m of basic volcanics and minor sediments—the Seigal Volcanics. This unit is overlain in turn by about 1000 m of dolomite, sandstone, and basic and acid volcanics, which make up the upper part of the Tawallah Group. Low-grade uranium mineralization, consisting of both primary and secondary minerals, is present in sandstone within the Westmoreland Conglomerate, and in faults and shears within the Seigal Volcanics.

The lower part of the succession on the Lawn Hill Platform, south of the Murphy Tectonic Ridge, consists of the Wire Creek sandstone (informal name) at the base, the Peters Creek Volcanics, and the Fish River Formation at the top. These units are similar in age to the Tawallah Group to the north. The Peters Creek Volcanics include both basalt and rhyolite, which are interlayered with dolomite, sandstone, and siltstone. This part of the succession is about 1500 m thick, and is overlain unconformably by a sandstone, dolomite, siltstone and shale sequence—the Fickling Group (formerly the Fickling Beds). This Group is about 1000 m thick, contains some copper and lead mineralisation, and may be correlated with the Mount Isa Group to the southeast, and the McArthur Group to the northwest. It is overlain unconformably by sandstone and siltstone of the Carpentarian or Adelaidean South Nicholson Group, which occupies the South Nicholson Basin.

Except near faults, the Cliffdale Volcanics and younger rocks are only gently folded. Most of the folding and faulting took place before the end of the Precambrian.

GEORGETOWN PROJECT, BY J. H. C. BAIN, B. S. OVERSBY, I. W. WITHNALL, E. M. BAKER, & D. R. WILSON.

STAFF: J. H. C. Bain[1], B. S. Oversby[1], I. W. Withnall[1] (GSQ), E. M. Baker[1] (GSQ) (all full time); A. G. Rossiter[2], K. J. Armstrong[2], D. R. Wilson[3], L. P. Black[4], M. W. Mahon[4], J. Mifsud[5], and P. L. Blythe[5] (part time).

[1]geology, [2]geochemistry, [3]geophysics, [4]geochronology, [5]drafting.

Introduction

The aims of the Georgetown Project, which started in 1972, are to produce revised geological maps at 1:100 000 scale, and to assess the mineral resources and potential of the Georgetown Inlier, north Queensland (Fig. M14). The immediate objective has been to map the *FORSAYTH*, *GEORGETOWN*, and *GILBERTON* 1:100 000 Sheet areas, to determine the relations between the main rock units, and to locate and catalogue all mines, prospects, and mineral occurrences. Geochronological studies and regional and detailed geochemical and geophysical surveys have been undertaken in conjunction with the geological mapping to help gain a comprehensive understanding of the geology.

So far the field activities indicated in Figure M14 have been completed, and the following maps and reports prepared:

(i) 1:25 000-scale geological compilation sheets of *FORSAYTH*, *GEORGETOWN* (BMR Record 1975/28), and *GILBERTON* 1:100 000 Sheet areas, and parts of *MOUNT SURPRISE*, *GALLOWAY*, *NORTH HEAD*, and *FOREST HOME* 1:100 000 Sheet areas.

(ii) Preliminary Edition of *FORSAYTH* 1:100 000 Geological Series map.

(iii) First Edition of *RED RIVER* 1:250 000 Geological Series map and accompanying Explanatory Notes.

(iv) Stacked profiles of airborne magnetic and radiometric data, *GEORGETOWN* 1:250 000 Sheet area.

(v) Reports on the geology, and on the mines and mineral deposits of the *FORSAYTH* Sheet area (GSQ Report 91), and on mineral exploration in the Georgetown region up to 1973 (GSQ Record 74/20).

(vi) Reports on both stream sediment and soil geochemical orientation studies in the Georgetown Inlier (BMR Records 1973/126, 1975/68).

Objectives for the next two years will be the publication of additional data and conclusions (in the form of maps and reports) derived from the previous four years' field and laboratory work. This will complete the first phase of the Georgetown Project.

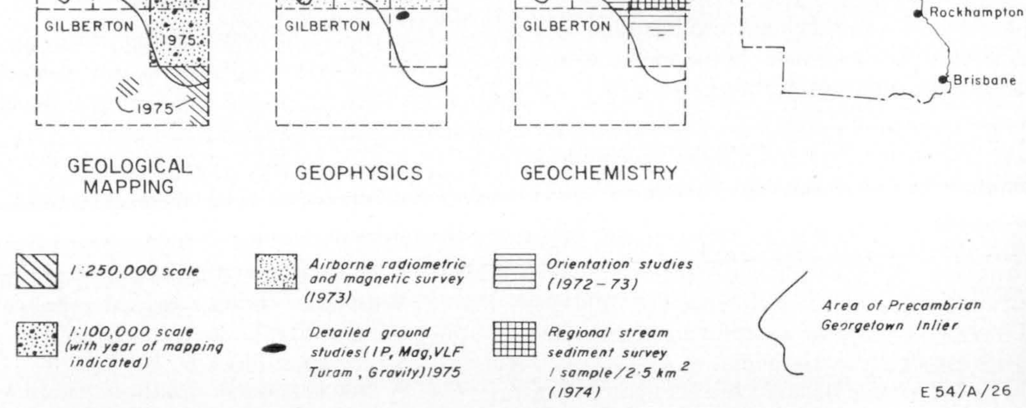

Figure M14 Geological, geophysical, and geochemical studies, Georgetown project, 1972-75

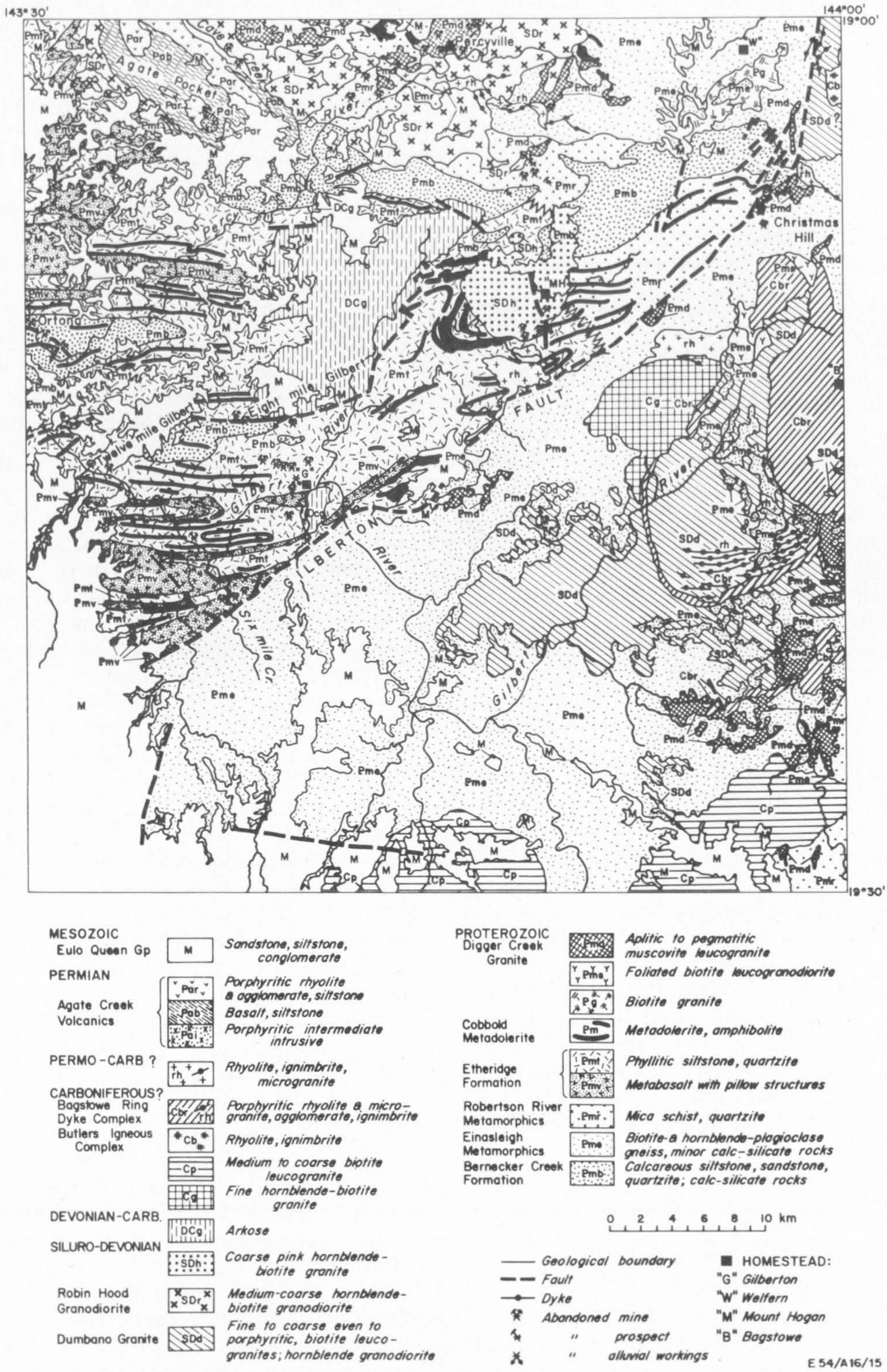

Figure M15 Generalized geological map, GILBERTON 1:100 000 Sheet area

During 1975 most of the geological field work was directed to mapping the *GILBERTON* 1:100 000 Sheet area (Fig. M15), using colour airphotos at 1:25 000 scale. An additional 1500 km² in the *MOUNT SURPRISE, GALLOWAY, FOREST HOME* and *NORTH HEAD* 1:100 000 Sheet areas was mapped to obtain further data on formations that extend beyond the *GEORGETOWN, FORSAYTH,* and *GILBERTON* 1:100 000 Sheet areas.

Geology of GILBERTON 1:100 000 Sheet area

Granites. The distribution of granitic rocks shown in Figure M15 differs from that shown on the published *GEORGETOWN* 1:250 000 map in that large areas previously mapped as Dumbano Granite are in fact partly Einasleigh Metamorphics and partly other granites, including small bodies of Precambrian Digger Creek Granite, an older previously unreported foliated biotite granodiorite, and a large body of probably late Palaeozoic hornblende-biotite microgranite. The foliated granodiorite was emplaced before or during the second deformation of the Einasleigh Metamorphics, and the Digger Creek Granite intrudes it. The Dumbano Granite has been subdivided into porphyritic biotite granite, hornblende-biotite granodiorite, and biotite leucogranite. The leucogranite appears to be the youngest of these units, and was emplaced after the second deformation of the Einasleigh Metamorphics: it may be Siluro-Devonian, as indicated by preliminary isotopic dating.

The boundaries of the Siluro-Devonian Robin Hood Granodiorite (previously called Robin Hood Granite, which also included some Digger Creek Granite) have been more precisely delineated. The Robin Hood Granite shown in the vicinity of Mount Hogan on the 1st and 2nd Edition 1:250 000 maps is a separate body of different, though probably related, granite.

Upper Palaeozoic granite along the southern edge of the Sheet area is a coarse biotite leucogranite of the Elizabeth Creek type; it contains some small cassiterite and wolfram deposits.

Metamorphic rocks. Most of the relationships between the main metamorphic units of the central part of the Georgetown Inlier have now been determined. Between Mount Hogan and Welfern, the Robertson River Metamorphics, which are the high-grade equivalent or 'schist phase' of the Etheridge Formation, grade into calc-silicate gneiss and granofels which are metamorphosed equivalents of the Bernecker Creek Formation. These in turn grade into a sequence of alternating biotite gneiss and calc-silicate gneiss mapped as Einasleigh Metamorphics. A general increase in intensity of folding can be traced from the Robertson River Metamorphics and Bernecker Creek Formation into the Einasleigh Metamorphics, in which three strong folding events and two weaker ones can be recognized, and samples have been collected for the purpose of attempting to date these events isotopically.

South and west of Gilberton homestead the Etheridge Formation and the lower-grade rocks of the Bernecker Creek Formation have been folded along east-trending axes, and show a well developed slaty cleavage. Folds formed during two later deformations are poorly developed to the south and west of Gilberton homestead, but are prominent to the north and east, where the intensity of these deformations was greater. Maximum deformation occurred in the Robertson River Metamorphics of the *FORSAYTH* Sheet area where three very strong folding episodes and at least one, and probably two, later, weaker ones have now been recognized by both us and workers from James Cook University, Townsville. Whether or not these later events had any effect on the rocks of the *GILBERTON* Sheet area has not been determined. The first two deformations were accompanied by regional metamorphism.

Low-grade rocks are faulted against high-grade calc-silicate rocks, biotite gneiss, and schist (Einasleigh Metamorphics) along the northeast-trending Gilberton Fault.

The field evidence indicates that the Etheridge Formation, Robertson River Metamorphics, Bernecker Creek Formation, and Einasleigh Metamorphics are stratigraphically equivalent, their present differences being due to differences in metamorphic grade and lithofacies. The biotite gneiss of the Einasleigh Metamorphics may have been derived from sedimentary rocks intermediate in composition between those of the largely pelitic Etheridge Formation and the calcareous Bernecker Creek Formation. The possibility that the Einasleigh Metamorphics include some older 'basement' gneiss can not be completely ruled out.

Large areas of basic metavolcanics, including pillow lavas and hyaloclastic breccias, have been discovered in the metasediments of the Etheridge Formation. They are best developed in the western third of the Sheet area north of the Gilberton Fault. Numerous sills of metadolerite and metagabbro intrude the metamorphics in the same area, and may be comagmatic with the metabasalt.

Agate Creek Volcanics. The Lower to Middle Permian Agate Creek Volcanics crop out in the northwest (Fig. M15) and in the adjacent part of the Forsayth Sheet area. It is the youngest Palaeozoic volcanic sequence known in the central Georgetown Inlier, and contains a greater proportion of basic volcanics than do older ones. The basic volcanic rocks are considerably thicker in the south and southwest than along the northeastern edge of the main outcrop area. In Agate Pocket they are interbedded with three fossiliferous siltstones that are probably lacustrine. Most agate occurrences in Agate Pocket are in the lower part of the basic volcanic rock sequence, below the lowermost siltstone. Complex interfingering of acid and basic volcanic rocks occurs in the southeastern part of Agate Pocket. The Agate Creek Volcanics evidently accumulated in a topographic depression which does not appear to have been bounded by faults.

Bagstowe Ring Dyke Complex. The western half of the Carboniferous(?) Bagstowe Ring Dyke Complex lies within the *GILBERTON* 1:100 000 Sheet area. No mineral deposits are known in this part of the complex, although the youngest granite intrusion in the centre of the complex contains a small wolfram deposit, situated about 20 km northeast of Bagstowe homestead.

Gilberton Formation. The Upper Devonian-Lower Carboniferous Gilberton Formation crops out in the central part of the Sheet area (Fig. M15). It is the oldest known of several Palaeozoic sequences of clastic sedimentary rocks in the central Georgetown Inlier, most of which are interbedded with and overlain by Carboniferous ignimbrites. Plant fossils are present in possibly lacustrine shale and siltstone in the lowermost part of the formation. Most of the formation consists of fluviatile pebbly arkose and conglomerate apparently derived from the north.

Mineral deposits. Mines at Gilberton, Mount Hogan, Percyville, and Christmas Hill have produced most of the gold taken from the *GILBERTON* 1:100 000 Sheet area. At Gilberton alluvial gold was most important, but numerous quartz reefs were also worked. The probably high proportion of 'specimen' gold won makes production figures based on battery records unreliable. The biggest nugget known from the field was found in Sandy Creek, and weighed about 1.7 kg. At Mount Hogan a large number of small mines worked a stockwork of auriferous quartz veins in a large area of sericitized rock within the southern part of a body of Robin Hood-type granite. The quartz veins contain minor lead and copper sulphides, and metatorbernite(?) was found on some dumps. Metatorbernite(?) also occurs at Percyville, where gold was won from pyrite- and chalcopyrite-bearing quartz veins in sericitized Einasleigh Metamorphics and Digger Creek Granite marginal to the Robin Hood Granodiorite. At Eight Mile Creek, Percyville, scheelite and bismutite occur with minor gold and rare molybdenite in quartz and pegmatite (possibly Digger Creek Granite) cutting Einasleigh Metamorphics; production has been minor. Tantalite occurs with bismutite in a similar setting at Dividend Gully, Percyville. At Christmas Hill gold was obtained from arsenopyrite-bearing quartz veins in sericitized Einasleigh Metamorphics and presumed Upper Palaeozoic rhyolite.

The gold and associated minerals at Mount Hogan and Percyville may have been introduced during the Silurian/Devonian, as indicated by the close spatial relation between the mineralization and the Siluro-Devonian granites there. Mineralization at Gilberton is not obviously related to any granite, although it is connected to that at Mount Hogan by a belt of minor alluvial and reef-gold occurrences. The mineralization at Christmas Hill may be Palaeozoic or younger, as it postdates Carboniferous(?) rhyolite.

Small argentiferous galena veins have been worked in Etheridge Formation on Six Mile Creek and in Robin Hood Granodiorite at

Cave Creek. Some copper has been won at Eight and Twelve Mile Gilbert from the oxidized parts of small quartz veins cutting Etheridge and Bernecker Creek Formation rocks and metadolerite. The Eight Mile mineralization is within a major but diffuse fault zone which also contains presumed Upper Palaeozoic rhyolite dykes and vent(?) breccias. The Ortona Mine, 13 km to the northwest, exploited copper-bearing quartz veins in metadolerite within the Bernecker Creek Formation. Amygdaloidal metabasalt on the Gilbert River 10 km west of Gilberton homestead contains chalcopyrite (which has not been worked).

Geology of GILBERTON 1:250 000 Sheet area

A brief helicopter reconnaissance of the southeastern quarter of this Sheet area was undertaken to check some of the pre-Mesozoic geology. The most notable result was the discovery of a hitherto unrecorded large shear zone cutting granites and metamorphics. This is 3 km wide, and trends north-northeast along the Stanwell River, southwest of Chudleigh Park homestead, and is the widest and most intense shear zone recorded in the Georgetown Inlier. It may be related to the marginal faults of the Broken River Embayment.

Geology of FOREST HOME 1:100 000 Sheet area

Reconnaissance mapping of part of the *FOREST HOME* Sheet area was undertaken to establish the distribution of, and relations between, the various rock types making up the western part of the Forsayth Granite. Three varieties of Forsayth Granite, two younger porphyries, and two large areas of hydrothermal alteration were mapped.

It appears that the oldest phase of Forsayth Granite was emplaced during the third deformation of Robertson River Metamorphics. Muscovite-biotite granite and related quartz-muscovite pegmatite intrude the three varieties of the Forsayth Granite.

The porphyries mapped are the Prestwood Microgranite (pink porphyritic biotite microadamellite) and a grey porphyritic biotite granodiorite in the Mount Darcy area, 30 km west of Georgetown, which contains ellipsoidal quartz phenocrysts and sporadic disseminated chalcopyrite.

Mount Turner, which was previously shown as a metamorphic roof pendant, consists of an area (about 12 km west of Georgetown) of about 10 km^2 of intensely hydrothermally-altered Forsayth Granite. The presence of malachite staining, limonite pseudomorphs of disseminated sulphides, and abundant copper weed indicate the anomolous copper content of the rocks. The alteration is similar to that in a Cu-enriched quartz-sericite alteration zone within the Mount Darcy porphyry. Surrounding this alteration zone are numerous radiating linear alteration zones, generally localized along shears. These are mineralized, and have dykes of altered rhyolite associated with them. Many small silver-lead lodes were worked in these peripheral alteration zones within a few kilometres of Mount Turner. This large Carboniferous or younger hydrothermal alteration system is worthy of further study, and is large enough to contain a low-grade copper deposit of exploitable size.

Geology of NORTH HEAD 1:100 000 Sheet area

Metamorphic rocks. The eastern part of the *NORTH HEAD* Sheet area was mapped to determine the extent of the 'schist phase' (Robertson River Metamorphics) of the Etheridge Formation. In places an abrupt change from phyllite to schist occurs, but elsewhere the change is more gradual. The change may be due either to variations in the thermal gradient during metamorphism or to the effect of later folding and consequent steepening of originally shallow-dipping isograds. The intensity of deformation evidently decreased westwards, as indicated particularly by second and third generation fold geometries.

Two large areas previously mapped as 'Cobbold Dolerite' in the vicinity of South Head homestead and in the Cobbold Creek area were found to consist dominantly of basic metavolcanics.

Mount Tabletop area. In the northeast corner of the Sheet area a hitherto unmapped, downfaulted block of arkosic sandstone, 20 km^2 in area, is overlain by rhyolite lava (on Mount Tabletop) and ignimbrite, and intruded by rhyolite plugs. The area lies midway between the Carboniferous Newcastle Range Volcanics and Cumberland Range Volcanics, and the arkosic sandstone is therefore probably also Carboniferous.

Geology of MOUNT SURPRISE and GALLOWAY 1:100 000 Sheet areas

Mapping of Newcastle Range Volcanics in these areas was undertaken to obtain as complete a picture as possible of the unit as a whole. That in the Galloway area has not yet been completed.

The sequence of Newcastle Range Volcanics in the Mount Surprise area is similar to that in the eastern Newcastle Range of the Georgetown area. Porphyritic microgranite and tin-bearing Elizabeth Creek-type granite apparently grade into each other in a dyke at Mount Adler, east of the Einasleigh River.

Clastic sedimentary rocks and intermediate to basic volcanic rocks in the lower part of the main Newcastle Range Volcanics sequence in the southern part of the *GALLOWAY* Sheet area apparently accumulated in a local depression. The southern edge of the depression coincides with a complex fault zone, which may have controlled subsidence during sedimentation and volcanism. Uranium and fluorite mineralization occurs in the sequence in this area.

Geophysics

Several detailed gravity traverses and four detailed IP, VLF, Turam, and magnetic grids were completed during a survey lasting eight weeks. The gravity traverses were designed to obtain sufficient detail for a structural interpretation of the Newcastle Range. The results indicate that a meaningful interpretation will not be possible. However, some useful structural information was obtained in the vicinity of Georgetown where a prominent north-south gravity ridge suggests that rock more dense than the outcropping Forsayth Granite is relatively close to the surface.

The detailed electrical and electromagnetic traverses were undertaken to determine the geophysical characteristics of selected mineral deposits and geological features.

A porphyry copper prospect at Mount Darcy, about 30 km west of Georgetown, was briefly investigated. IP and geochemical anomalies commonly correlate well. IP anomalies also suggest the presence of areas of mineralization not detected by geochemistry. However, no other techniques used gave significant results.

Two mineralized lineaments 4 km south of Georgetown were surveyed. VLF and resistivity appear to be useful tools for tracing such lineaments, and IP should detect any sulphide mineralization present.

Big Reef, an auriferous quartz-veined shear south of Forsayth, appears to be relatively complex. The main reef gives a recognizable geophysical response, but a zone 300 m wide immediately north of the reef, and parallel to it, and probably extending for its whole length, gives an enhanced IP and electromagnetic response. The offset of the IP and EM anomalies suggests that both massive and disseminated sulphides are present. However, the EM anomaly could result from a non-metallic conductor such as graphite.

The Jubilee Plunger reef, 1 km southwest of Robin Hood homestead, appears to be poorly mineralized. A small enhanced IP response is the only evidence of any concentration of sulphide. No other technique was directly useful in detecting mineralization. The reef has a magnetic signature which may be useful in tracing it farther north.

These orientation studies show that IP is the most useful tool in the search for sulphide mineralization in the Georgetown Inlier. VLF may be of use where the strike direction is roughly east-west, and rapid tracing of shallow structures is required.

Geochemistry

Regional stream sediment and local soil geochemical work carried out in the Georgetown region is reported elsewhere in this *Summary* by Rossiter. Further work in the *GEORGETOWN* and *GILBERTON* 1:100 000 Sheet areas in planned for 1976.

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. Further samples for dating were collected during the year.

Drilling

About 300 m of diamond drilling, comprising two holes in the Jubilee Plunger reef and two on the Big Reef lineament, was undertaken to investigate geochemical and geophysical anomalies, and to obtain fresh rock from the mineralized alteration zones. These specimens will be examined petrographically and chemically in a study of the gold/silver mineralization.

NORTH SEPIK PROJECT, PAPUA NEW GUINEA, BY D. S. HUTCHISON

STAFF: M. S. Norvick (resigned April), D. S. Hutchison (on study leave until August)

The aim of the project was the reconnaissance geological mapping and preliminary assessment of the mineral potential of the North Sepik region (Torricelli 'block' in Fig. M16), which comprises the *VANIMO*, *AITAPE*, *WEWAK*, and *SEPIK* 1:250 000 Sheet areas. Field work was completed in 1973. During the year work continued on the compilation of the four geological sheets and on the preparation of reports.

General geology

The region consists of late Mesozoic and lower Tertiary intrusive, volcanic, and metamorphic basement rocks which are unconformably overlain by Neogene and Quaternary marine and nonmarine sediments. A central east-trending mountain zone separates mainly volcanic basement to the north from metamorphic basement (*Salumei Formation*, metamorphic phase) to the south, and is made up of the following basement units: *Torricelli Intrusive Complex* (late Cretaceous to early Miocene basic and intermediate intrusives), *Bliri Volcanics* (= ?Paleocene to early Miocene basic and intermediate volcanics), *Prince Alexander Complex* (mixture of early Cretaceous to early Miocene intrusives and metamorphics), and *Mount Tuni Complex* (a mafic/ultramafic complex).

The overlying sediments were deposited in elongate, coeval troughs which flank the central basement zone. In places, the sediments exceed 3000 m in thickness.

In the west the unconformity separating the basement and cover rocks is at the base of the Miocene (within planktonic foraminiferal zone N4), but it gets younger eastward, suggesting progressive filling of the troughs from the west.

Economic geology

The only mineral of known economic importance in the region is alluvial gold. It occurs in two principal localities: in the Prince Alexander Mountains north of Maprik (1, Fig. M16), and in the Border Mountains (2, Fig. M16), in the southwestern part of the region. In the former occurrences the immediate source of the gold is the coarse polymict conglomerate at the base of the cover succession. In the Border Mountains, the source of the gold is unknown. Minor occurrences of sulphides in veins, and of platinum and nickel are known, but are uneconomic.

The region has been subjected to spasmodic petroleum exploration since the early 1920s, and although success has evaded them the geological mapping carried out by various companies has provided much valuable information for the current project. Large, gentle anticlines in the southern part of the region (south of the central mountain zone) were initially thought to be attractive petroleum targets; however, a recent test of the core of one of them indicated metamorphic basement at a very shallow depth. The flanks of these anticlines could still be worth investigating for stratigraphic traps, and Miocene and Pliocene reef carbonate reservoirs could exist in the northwestern part of the region.

Reporting

Preliminary Editions of the *VANIMO*, *AITAPE*, and *WEWAK* map sheets were issued during the year, and the preparation of the First Editions and accompanying Explanatory Notes is expected to be completed by March, 1976. A report on the basement geology of the region has been prepared by Hutchison. The manuscript for a Bulletin covering all aspects of the geology of the region is scheduled for completion by June, 1976.

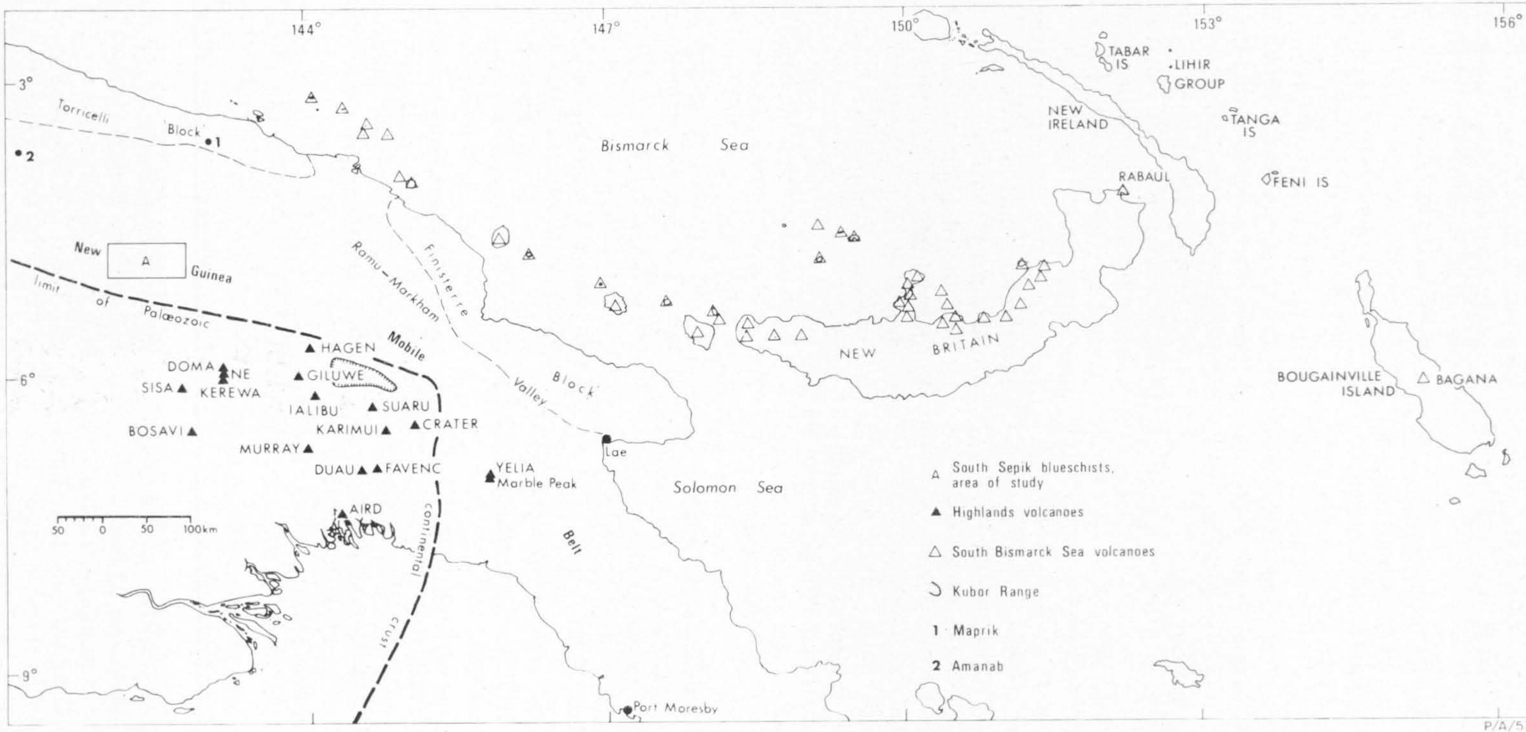

Figure M16 Current Papua New Guinea projects

SOUTH SEPIK BLUESCHIST PROJECT, PAPUA NEW GUINEA, BY R. J. RYBURN

Introduction

Ryburn returned in August from two years' leave at the University of Auckland, where he undertook a Ph.D. study of the petrology, metamorphism, and tectonic history of blueschist and associated rocks in the south Sepik area of Papua New Guinea. Originally discovered by the 1967 BMR Sepik Party, the blueschists were examined in detail during the 1971 BMR West Sepik Survey.

General geology

The blueschists are exposed in an area 50 km long and 15 km wide on the northern fall of the Central Range (Fig. M16). Their major and trace-element chemistry indicates that they were originally gabbros and basalts of oceanic affinities, and are the metamorphosed equivalents of ophiolitic basalts and gabbros to the south. The metamorphic grade increases northwards from the prehnite-pumpellyite zone through the lawsonite-glaucophane zone to the epidote-glaucophane zone. There are also some diapiric melange zones containing large blocks of coarsely crystalline blueschist, amphibolite, and (rarely) eclogite. These blocks are generally of higher metamorphic grade than that of the nearby, undisturbed (autochthonous) country rocks, and are set in a matrix of talc-actinolite schist and pelitic schist.

Petrology and electron-probe microanalyses reveal a marked similarity between the Sepik blueschists and those of New Caledonia and, to a lesser extent, the European Alps. The chemistry of co-existing garnets and pyroxenes in assocated eclogites suggests temperatures of 350°–650°C and pressures of 8–15 kb during metamorphism, indicating that these once supracrustal rocks were carried to depths of up to about 50 km.

The blueschists lie immediately south of a major dislocation, the Frieda Fault, north of which are low to moderate-pressure metamorphics. Available isotopic age data suggest that the metamorphism on both sides of the fault took place during the late Oligocene or early Miocene. The two contrasting metamorphic terrains constitute a paired metamorphic belt, similar to those of Japan, Sulawesi, and New Zealand. Unlike these examples, however, the high-pressure terrain lies on the continental side of the low-pressure terrain. The boundary between the two terrains, termed the *Median Tectonic Line*, can be traced both eastwards, through the Ramu-Markham Fault Zone and along the Owen Stanley Fault, and westwards into Irian Jaya.

Along with other considerations, the polarity of the paired metamorphic belt strongly suggests that *northward-dipping* subduction took place beneath the northern belt in the Lower Tertiary, and that the Median Tectonic Line represents the suture of a mid-Tertiary collision between the northern margin of the Australian continent and the eastern extension of the Banda Arc (which includes New Britain). Ophiolite sequences north of the Median Tectonic Line are on the leading edge of the upper plate. These northern sequences include the Papuan Ultramafic Belt, the Marum Ultramafic Complex, and also two small occurrences in the south Sepik area, in one of which the ophiolites clearly dip northwards.

The recognition of a Median Tectonic Line has profound consequences for the interpretation of New Guinea geology. In particular, all Oligocene and older rocks north of the line are probably unrelated to those south of the line; before the collision the two terrains may have been separated by an ocean basin that was hundreds or even thousands of kilometres wide. It is suggested that the south Sepik blueschists represent intra-oceanic islands or guyots which were detached from the lower plate, and later engulfed by partly subducted sediments at the leading edge of the Australian craton. Their subsequent rapid uplift and exposure may be due to isostatic readjustment.

NEW BRITAIN PROJECT, PAPUA NEW GUINEA, BY R. J. RYBURN

Since returning in August from study leave at the University of Auckland, Ryburn has resumed the preparation of a Bulletin on the geology of New Britain. This will present the results of regional mapping of the entire island. The 1:250 000 geological maps and Explanatory Notes for New Britain are either published or in press.

VOLCANOLOGY AND ORE GENESIS, PAPUA NEW GUINEA

South Bismarck Sea volcanoes, by R. W. Johnson

This study of the geology and petrology of the south Bismarck Sea volcanoes (Fig. M16) was undertaken to help elucidate the present-day tectonic setting of the volcanoes, and to determine the origin of their magmas. It is expected to be completed in 1978.

A proposed Bulletin on the major-element chemistry and tectonic setting of volcanoes at the southern margin of the Bismarck Sea was revised and updated in the light of recently published papers. In particular, the model accounting for the zig-zag distribution pattern of the volcanoes of central New Britain and the Witu Islands was amended and developed. The bifurcation, west of 150°E, of the submarine trench south of New Britain is now taken to indicate the presence of a thrust slice sandwiched between the downgoing Solomon Sea plate and the static South Bismarck plate beneath west New Britain, rather than the presence of a small separate plate. This thrust slice is thought to be extracting heat from the overlying South Bismarck plate, thereby preventing partial melting in the upper mantle. Melts derived from the downgoing Solomon Sea plate and rising into the upper mantle at depths greater than about 100 km may be substantially hotter west of 150°E than east of 150°E, and this could account for the volcanism that gave rise to the Witu Islands. This hypothesis is discussed in detail in a paper by Johnson (in press).

The regional variations in major-element chemistry in the South Bismarck Sea volcanoes have been re-evaluated using program BMD05R (Dixon, *Univ. Calif. Publ. Autom. Comput. 2*, 1971) with modifications by Mayo & Long (BMR Record, in prep.). This program calculates a series of regression lines for any two oxides (or oxide ratios), increasing in the degree of the polynomial until a line of best fit is obtained. The regression lines have proved valuable in simplifying the rather complex inter-element relationships found in the rocks of the south Bismarck Sea volcanoes.

Tabar-to-Feni Islands, by R. W. Johnson

This study was undertaken in conjunction with D. A. Wallace, of the Central Volcanological Observatory, Rabaul, to determine the geology and petrology of these volcanic islands which lie to the northeast of New Ireland. Some geological information had been obtained by the late G. A. M. Taylor, and the principal objective was to combine his results with those of Wallace, who, with I. H. Crick, later surveyed the islands independently. The study is expected to be completed in 1978.

The volcanic rocks of the Tabar, Lihir, Tanga, and Feni Islands range from pre-middle Miocene to Pleistocene, and show an exceptionally wide range in chemical composition. Strongly silica-undersaturated types, some of which contain phenocrysts of haüyne and analcite, are basanite, tephrite, olivine nephelinite, phonolitic tephrite, and tephritic phonolite; these are especially common in the Tanga and Feni Islands. Less undersaturated and silica-saturated types are alkali and 'transition' basalt, trachybasalt, and trachyandesite; these are well represented on Tabar and Lihir Islands. Silica-saturated trachyte is found on all the island groups except the Lihir Islands, and some undersaturated trachyte is present in the Tanga Group. Tholeiitic basalt, andesite, and dacite, the predominant volcanic rocks of the South Bismarck Sea volcanoes, appear to be absent. K_2O/Na_2O values are mainly between 0.5 and 1, and TiO_2 contents are notably low (mainly less than 1 percent).

The tectonic conditions which led to the development of these magmas are uncertain. The magmas may be related to a slab of downgoing lithosphere, but the islands are not underlain by a zone of intermediate or deep-focus earthquakes at present. An alternative model involving an isostatically controlled fault zone beneath the islands is being investigated: faulting could have been triggered by differences in crustal thickness and in gravity between the Bismarck Sea area and part of the adjacent southwest Pacific plate.

Bagana Volcano, by R. J. Bultitude

This study was undertaken to elucidate the geology, petrology, and eruptive history of Bagana Volcano, probably the most active volcano in Papua New Guinea. The writer spent 12 days in November, 1973, examining parts of the volcano, and has since prepared a report on Bagana, a condensed version of which will appear in the Taylor Memorial Volume.

Bagana is situated in the central part of Bougainville Island (Fig. M16). It appears to be built up of steep-sided blocky andesitic lava flows, up to about 150 m thick, and minor pyroclastic deposits. Since 1943 at least 18 lava flows have reached the lower or intermediate slopes of the volcano, and Bagana has been almost continuously active since 1947. Eruptions usually consist of thick, slow-moving, blocky lava flows from the summit area, sometimes accompanied by violent explosive activity which produces nuées ardentes and ash clouds. Major eruptions occurred in 1950, 1952, and 1966. From 1972 to early 1975 lava was extruded more or less continuously, but there were no reports of any explosive activity.

The Bagana lavas are porphyritic, especially in plagioclase. Clinopyroxene is the next most abundant phenocryst phase, followed by opaque oxide, brown hornblende, and orthopyroxene. Some lava specimens contain rare small olivine phenocrysts, generally to the exclusion of orthopyroxene. The lavas are predominantly low-silica andesites, and are fairly typical of calcalkaline andesites from island arcs.

Papua New Guinea highlands volcanoes, by D. E. Mackenzie

The aims of this project are to study the nature, origin, and possible economic significance of the late Cainozoic volcanic centres which cover a large part of central mainland Papua New Guinea (Fig. M16). The field work was carried out in 1968, 1970, and particularly 1971. A report on the work, due for completion in March, 1976, will be submitted to the University of Melbourne as a Ph.D. thesis, and will be published as a BMR Bulletin.

Most of the Highlands volcanoes are underlain by up to 10 km of Mesozoic and Tertiary sedimentary and volcanic rocks resting on Palaeozoic sialic basement about 25 km thick. The area was strongly compressed and uplifted during the Miocene and Pliocene. Two volcanoes, Mount Yelia and Marble Peak, are situated on the New Guinea Mobile Belt. A restricted 'pocket' of intermediate-depth (170-190 km) seismicity indicates underthrusting of 'cold' material beneath the Mount Yelia area. Elsewhere in the region, seismic activity is restricted to crustal and uppermost mantle (up to 50 km) depths, and there is no evidence of subducted oceanic lithosphere.

The volcanoes are generally Quaternary, although there is evidence of some volcanism in the late Pliocene. Most are deeply eroded simple or composite conical strato-volcanoes. Exceptions are Mount Yelia, which is only slightly eroded, Mount Giluwe, which is an eroded shield volcano, and the Aird Hills, which appear to be a ring-like cluster of lava domes.

About 600 specimens have been examined microscopically, and detailed mineralogical and geochemical investigations have been carried out on 185 of these. Mounts Hagen, Giluwe, Suaru, Karimui, Bosavi, Murray, Duau, and Favenc, and Crater Mountain consist largely of porphyritic basalts which range from saturated and oversaturated (in SiO_2) potassium-rich types (e.g., Mount Hagen) to more sodic types (e.g., Mount Bosavi); the basalts are overlain by typical island-arc-type andesites. Mounts Ialibu, Ne, Kerewa, and Yelia, Doma Peaks, and Aird Hills consist predominantly of similar andesites. The more mafic basalts on Mounts Bosavi, Duau, and Favenc contain rare 'plutonic' ultramafic inclusions, and some olivine phenocrysts in Mount Hagen basalts have a similar high-pressure origin. The data indicate an upper mantle origin for the lavas. Each volcanic centre is petrographically and chemically distinct, although there are some similarities between Mounts Hagen and Giluwe, and between Mounts Murray, Duau, and Favenc. Basalts from volcanoes near the Kubor Range (Hagen, Giluwe, Suaru, and Karimui) are somewhat more oversaturated in silica, higher in K_2O relative to Na_2O, higher in Rb, Ba, and other 'incompatible' trace elements, and have lower $^{87}Sr/^{86}Sr$ than those from centres farther to the south and southwest, but there are no regular trends in any direction.

It is postulated that most of the magmas were generated in diapirs rising from the low-velocity layer of the upper mantle. The rise of these diapirs was related to Pliocene buckling and uplift of the overlying lithosphere. Variations in diapir, and hence magma, composition could have been caused by lateral migration of interstitial fluids rich in 'incompatible' elements towards areas of greatest lithospheric uplift and disturbance, such as the Kubor Range area (Fig. M16). Further variations in magma composition have been caused by wall-rock reaction, zone refining, crystal fractionation, differing depths of magma segregation, and variations in thickness, competence, and fracturing of the crust. Most of the andesites probably differentiated from basaltic magmas deep in the crust, but those of Mount Yelia and Marble Peak may be related to underthrust lithosphere.

Basaltic lavas of the highlands volcanoes commonly contain about 100 ppm Cu, mainly as a groundmass sulphide phase, but the amount of Cu decreases in the more fractionated rocks, and the most siliceous andesites contain less than 10 ppm Cu. It is suggested that Cu has been lost from the andesites, in which it should normally be enriched, perhaps in fluids capable of producing porphyry-type copper mineralization and alteration. Indications of such alteration are present on Mount Murray, and could be present beneath other centres, but any mineralization would probably be at depths of over 1 km.

G. A. M. Taylor Memorial Volume, by R. W. Johnson

A volume entitled 'Volcanism in Australasia' is to be published in honour of the late G. A. M. Taylor, G.C., who served for more than twenty years as a BMR volcanologist concerned with Papua New Guinea.

The volume will consist of a biography of Taylor by N. H. Fisher, a former Director of BMR, and twenty-eight original research papers dealing with aspects of volcanism in Papua New Guinea, Australia, Indonesia, the British Solomon Islands, Tonga, and New Zealand. More than forty papers were originally proposed for publication in the volume, but several of these were not accepted after the reviews of referees had been taken into account. Seventeen of the papers finally chosen are concerned with volcanism in Papua New Guinea. BMR geoscientists are authors (or co-authors) of fifteen papers, ten of which are by officers of the Geological Branch, and five other contributions are by former officers of BMR.

The volume is to be published by the Elsevier Scientific Publishing Company (Amsterdam), the editor is R. W. Johnson, and the expected date of publication is April, 1976.

PETROLOGICAL, GEOCHEMICAL, AND GEOCHRONOLOGICAL LABORATORIES

Supervising Geologist: K. R. WALKER

Professional Staff: K. R. Walker, A. D. Haldane, R. W. Page, John Ferguson (from November), A. Y. Glikson, S. E. Smith, L. P. Black, J. W. Sheraton, R. N. England, B. I. Cruikshank, D. J. Ellis (to June), A. G. Rossiter, C. M. Gardner, G. R. Ewers (from July), P. A. Scott (from August), J. E. Mitchell (part time)

Technical Staff: M. W. Mahon, 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, J. L. Fitzsimmons (from January), P. J. Swan (to May—transferred to clerical position)

Trainee Technical Officers:
(all part time) G. B. Price, C. R. Madden, I. M. Donald, J. H. Pyne, J. M. Purcell

INTRODUCTION, by K. R. Walker

Work on projects proceeded steadily throughout the year, together with consolidation of the analytical laboratories after the re-equipping program of recent years. All major analytical instruments have outputs for data processing, and most are now on-line to computers. This year the X-ray diffraction equipment was fitted with an automatic sample feeder and measuring set, and it is planned to connect this also to BMR's central computer for on-line data processing. Many programs have been modified during the year to suit the new facilities.

The Geochronology Group again achieved a record in the quantity of analytical data obtained for their project work, largely owing to an increase in instrument time available to BMR on the shared facilities in the joint BMR/ANU geochronology laboratory. We acknowledge the co-operation and assistance of the Director and staff of the Research School of Earth Sciences in the running and maintenance of this laboratory.

Geochronological research has concentrated on the Arunta, Tennant Creek, and Alligator Rivers area of the Northern Territory, and on the Mount Isa/Cloncurry, Georgetown Inlier, and Herberton/Mount Garnet districts of Queensland. Some geochronological assistance was given to the Geological Survey of Tasmania during the latter part of the year.

In April, Page was awarded a PSB Scholarship to study for 13 months the latest techniques of zircon separation and analysis for U-Pb dating at the Geophysical Laboratory of the Carnegie Institution of Washington. It is hoped that the U-Pb age-determination procedure will provide a means of obtaining the original ages of some of the oldest metamorphic rocks in the Mount Isa and Alligator Rivers areas, and elsewhere, as the need arises.

Geochemical survey work proceeded vigorously during the year; results of orientation work on stream sediment sampling in the Georgetown and Westmoreland regions done in previous years were reported, as well as the results of detailed investigations at the Jubilee Plunger mine. A further report on detailed work at the Big Reef and Two Nicks gold mines is in progress. Regional work in the *FORSAYTH* 1:100 000 Sheet area is nearing completion, and stream sediment sampling in the *SEIGAL* and *HEDLEYS CREEK* 1:100 000 Sheet areas was carried out in the 1975 field season. Where geochemical anomalies have been found they have been sampled in more detail, and in some cases tested by drilling, as at the Jubilee Plunger mine in the Georgetown Inlier. The results of these more detailed geochemical investigations have been reported in separate Records.

Work on pollution studies continued at a reduced level; monitoring in the Molonglo River at Burbong and in Lake Burley Griffin continued throughout the year. Haldane continued as a member of the IDC Subcommittee on water quality.

The geochemistry of the Tennant Creek mineral field is being written up, now that the analytical work on the Warramunga sediments and the ironstones is complete.

At the instigation of the Geological Survey of the Northern Territory, orientation sampling of the Cullen Granite has been carried out to study its geochemistry in relation to adjacent mineralization.

Project work in the Petrological Group involved mainly continuing studies of igneous and metamorphic rocks in the Arunta Block, in Antarctica, and in the Mount Isa/Cloncurry region, and the completion of work in the Westmoreland region. An investigation of the various rock units in the Pine Creek Geosyncline is proceeding, and petrological and geochemical study of rock relationships will include a study of the uranium mineralization and its origin.

Some unusual feldspathoidal lavas from volcanic islands off the cost of New Ireland, PNG, have received detailed study, and an examination of some magnophorite-bearing rocks from Antarctica is in progress.

A collaborative project is under way amongst the petrologists to study the alkaline ultramafic rocks of Australia, owing to the increasing recognition of these and associated rocks in this country, and because of their importance in understanding Upper Mantle rocks and minerals.

The IGCP project on 'Archaean Geochemistry' has been endorsed as a key project, and studies initiated this year on rocks from the Warrawoona Succession in the Pilbara will contribute to it. Investigation of the tectonic and geochemical aspects of Archaean terrains is continuing, and recently the results of work on rocks from the Transvaal and Rhodesia were published.

Laboratory researchers were involved in several current field projects, and in others where reporting is still in progress. Ten members of the professional staff spent an aggregate of 88 man-weeks in the field, and were assisted in part by three of the laboratory technical staff who spent a total of 9 man-weeks in the field.

Much of the work of the laboratory has been published in outside journals; 34 manuscripts were prepared during the year. One Bulletin and two Reports are about to be issued, and another Bulletin is in preparation. Two papers have been submitted to the new BMR Journal planned to appear in 1976. Eleven Records were issued, and four are in preparation. Ten papers have been published in outside journals, and three have been submitted.

The laboratory continues to be involved in the training scheme for Technical Officers, and the practical experience that Trainee Technical Officers receive in the Geological Branch is co-ordinated in the laboratory. Trainees undertake a 4-year course at the Canberra Technical College, during which time they also obtain practical experience in various aspects of BMR work. At present seven areas within the Branch participate in the scheme, and this year 12 science trainees were employed in these areas. Five of them received periodic instruction in the Metalliferous Laboratory. Instruction in laboratory procedures was also given to a Colombo Plan student from Korea and a technician from the Geological Survey of PNG.

The results of work done by the laboratory groups in Petrology and Mineralogy, Geochemistry, and Geochronology follow.

PETROLOGY AND MINERALOGY

Arunta Complex, N.T., by A. Y. Glikson

The area under consideration includes three large outcrops of mafic granulite, anatectic gneiss, intrusive granitic gneiss, and minor anorthositic and ultramafic rocks occurring north of the Chewings Range within the *HERMANNSBURG* 1:250 000 Sheet area. A small part of the basement gneiss of the Chewings Range is also included. The petrological and geochemical investigations follow the 1:100 000-scale mapping of the *ANBURLA* and *NARWIETOOMA* Sheet areas, which has now been completed. The objectives of the petrological-geochemical study are (1) to identify the geochemical characteristics and through them the origin of the mafic granulites and amphibolites which constitute the bulk of the Mount Hay massif; (2) to ascertain the trace-element characteristics of the acid gneisses and the mafic rocks, to determine if the acid phases originated by partial melting of the spatially related mafic bodies, or by allochthonous intrusion; (3) to observe the chemical changes which take place upon partial melting of the mafic rocks, and hybridization of the ensuing acid magma, with emphasis on the search for criteria for distinguishing the acid rocks (orthogneisses) from those formed by high-grade metamorphism and/or partial melting of sequences consisting of quartzo-feldspathic sediments and/or acid volcanics, as well as minor mafic rocks; (4) to examine possible implications of the data for the problem of the nature of the rocks which underlie the Burt Plain to the north, particularly in view of the Papunya gravity anomaly (over 50 mGal); and (5) to compare the rocks with the Reynolds Range metamorphics which occur to the north of the Burt Plain, and which were the subject of earlier studies by A. J. Stewart et al.

During the year three weeks were spent in the Narwietooma area. With the completion of the field work, a petrographic study of about 350 specimens is under way, and is aimed at selecting about 100 rocks for major- and trace-element analysis. Some isotopic Rb/Sr work may be warranted in order to elucidate the genetic relations between the mafic bodies and the gneisses.

Pilbara region, W.A., by A. Y. Glikson

Volcanic rocks of the Warrawoona Succession and stratigraphic equivalents within the *MARBLE BAR*, *NULLAGINE*, *YARRIE*, *PORT HEDLAND*, *ROEBOURNE*, and *PYRAMID* 1:250 000 Sheet areas include thick sequences (up to 12 000 m) of mafic to dacitic lavas, minor ultramafic rocks, dolerite, intermediate to acid agglomerate and tuff, and intercalated chert, jaspilite, shale, and carbonate rocks. *MARBLE BAR* and *NULLAGINE* have recently been mapped by the Geological Survey of Western Australia, and the stratigraphic succession is (in ascending order): Talga-Talga Subgroup; Duffer Formation; Salgash Subgroup; Wyman Formation. The

Talga-Talga and Duffer units consist principally of mafic and dacitic volcanics respectively and are intruded by granodiorites dated at ca 3.1 b.y. The Duffer Formation is capped by a regionally extensive chert unit (Marble Bar Chert), and includes acid volcanic lenses with which Cu, Pb, Zn, and Mo mineralization is associated in places.

The objectives of the present study, which has been accepted as part of the IGCP Archaean Geochemistry project, are:

(1) To determine the trace-metal characteristics of the various volcanic units to assess stratigraphically controlled chemical variations and possible diagnostic characteristics of both mineralized and barren volcanic units.

(2) To study the major-element and trace-element distribution patterns in the metamorphosed volcanic rocks in an attempt to elucidate their primary chemical characteristics and the effects of alteration on sheared, contact, and mineralized zones.

(3) To study possible correlations between degrees of alteration and base metal redistribution.

(4) To interpret the petrogenetic and tectonic significance of primary petrochemical trends.

(5) To obtain suitable material for rare-earth and isotopic studies, part of which may be carried out in other laboratories collaborating in the 'Archaean Geochemistry' project.

The study is being carried out in cooperation with the Geological Survey of Western Australia.

During the year six weeks were spent in the field. Sampling was carried out in the northeastern part of *MARBLE BAR*, principally along the Coongan River, the Talga-Talga River, and Chinaman Creek, but also in a number of other scattered localities in *MARBLE BAR*. About 400 samples were collected from the Talga-Talga Subgroup, Duffer Formation, and Salgash Subgroup. A few specimens were also collected from the Wyman Formation and the Honey Eater Formation (mafic to acid volcanics; part of Gorge Creek Group overlying the Warrawoona Succession). Sampling localities were plotted on RC9 (1:85 000) photographs. Most specimens collected did not react with 20 per cent HCl, and are thus probably relatively free from carbonate, although they could contain dolomite and ankerite. It is hoped that the problem of the masking of original igneous characteristics through extensive open-system chemical redistribution may be overcome by the study of the least altered successions, followed by selection of the least carbonated, chloritized, epidotized, silicified, and saussuritized samples in thin section. Probably between 100 and 150 rocks of the 400 or so collected will be selected for chemical analysis, and the results of this work should provide a basis for comparison with the Warrawoona Succession in other parts of the Pilbara, as well as with altered rocks in the Marble Bar area itself.

Archaean crustal studies, by A. Y. Glikson

The continuing review of Archaean literature, visits to Archaean terrains, and collaborative studies with university workers have resulted in further development of concepts relevant to the nature of the early terrestrial crust and the origin of Precambrian shields. A collaborative geochemical study of the major elements, trace elements, and rare-earth elements of acid volcanic and plutonic rocks from the Barberton Mountain Land (Transvaal) was carried out with S. R. Taylor, of ANU, and the results have been reported in a paper accepted for publication in *Geochimica et Cosmochimica Acta*. A contribution was made to the Leicester conference on 'Early History of the Earth' (NATO-sponsored), and will appear in a book under this title. It is increasingly apparent that fundamental analogies can be drawn between the greenstone-granite systems of Western Australia, India, the Transvaal, and Rhodesia, and that this analogy is supported by geochemical studies currently being conducted in these areas. The origin of the earliest volcanics in these terrains, either as oceanic crust, or as the product of impact-triggered volcanism (D. H. Green, *Earth Planet. Sci. Lett.* 15, pp. 263-270, 1972), is a subject of continuing review.

Archaean Geochemistry project, by A. Y. Glikson

Following the endorsement of this project by the International Geological Correlation

Program Board as a potential major project in 1974, an international project working group was convened by Glikson in Leicester, U.K., on 8-9 April, 1975. The group consisted of 20 people from seven countries (USA, Canada, UK, Denmark, South Africa, India, and Australia). Research priorities and organization of the project were discussed and recommended as a basis for the formulation of a project working plan. The group elected Professor A. M. Goodwin (Toronto University) as project chairman, and Dr G. N. Hanson (State University of New York at Stony Brook) as project secretary. Subsequently the project was endorsed by the IGCP Board as a 'key project', and a project statement has been finalized and distributed. A meeting of some members of the project working group took place in Moscow in September, 1975. A second meeting is planned for Sydney during the International Geological Congress, and a third meeting in India in 1977. The objectives of the project are to foster collaboration between active research workers, encourage joint ventures in the field, and organize meetings and field seminars in Archaean terrains, hopefully with the assistance of UNESCO, IUGS, and government institutions.

Antarctic geochemistry and petrology, by J. W. Sheraton & R. N. England

Petrographic and geochemical investigations of rocks from the southern Prince Charles Mountains continued to supplement mapping carried out during the summer seasons of 1972, 1973, and 1974. Chemical analysis of about 200 samples (including some from the Northern Prince Charles Mountains and Mawson Coast areas) for 10 major and 17 minor elements were completed, and the data are now being interpreted. Electron microprobe studies of basic granulites from the north Mawson Escarpment will be carried out shortly.

Chemical analysis of a magnophorite-bearing mafic dyke rock from Mount Bayliss has confirmed that it belongs to the rare ultrapotassic suite previously reported from only four localities: Leucite Hills, Wyoming; Western Kimberley region, Western Australia; Montana; and southeastern Spain. It is particularly rich in TiO_2, K_2O, P_2O_5, F, Rb, Sr, Zr, and Ba, and poor in Al_2O_3.

Basic igneous rocks, Mount Isa/Cloncurry area, Queensland, by D. J. Ellis

A field and laboratory study of the Precambrian intrusive and selected extrusive basic igneous rocks of the region from Mount Isa to east of Cloncurry has been completed.

It has been found that there are at least four separate episodes of basic intrusive activity, though these are not represented everywhere in the study area. There is evidence of systematic spatial and temporal variations in the geochemistry of these rocks, especially with respect to Ba, Rb, Sr, and K, which increase westwards; these elements appear to have behaved somewhat as they do in modern island-arc volcanic rocks in which they increase with depth to the subduction zone. However, consistent differences in the absolute abundances of certain trace elements also exist in comparison with modern island-arc volcanic rocks. There is an increase in the average K and Rb contents of successively younger basic rocks in that part of the Eastern Succession which has been studied. Calc-alkaline andesites have been recorded for the first time in the Mount Isa region from the Marraba Volcanics.

Lower Proterozoic rocks, northwest Queensland, by R. N. England & C. M. Gardner

Work commenced on the semi-detailed mapping of the *DUCHESS* 1:250 000 Sheet area and parts of several adjoining 1:100 000 Sheet areas at 1:100 000 scale with a view to isolating petrological problems for later study. In the initial two-month field season, preliminary mapping of the *OBAN* and *DUCHESS* 1:100 000 Sheet areas was undertaken. Progress in this mapping is reported in the relevant field section of this *Summary*.

Granites and acid volcanics, Westmoreland area, Qld and N.T., by C. M. Gardner

Most of the time spent on this project was given to preparation of a Record entitled 'Precambrian Geology of the Westmoreland region, northern Australia: Part III. Nicholson Granite Complex and Murphy Metamorphics.'

Further isotopic dating was completed by A. W. Webb (AMDL) early in the year, and confirmed that the Cliffdale Volcanics are unconformable on older phases of the Complex, and are intruded by younger, high-level phases. The total time span of intrusion was probably not more than about 70 to 90 m.y. This fact, plus the fact that the Cliffdale Volcanics are closely related geochemically to both the older and the younger granites, justifies use of the term 'Complex', even though intrusive activity was interrupted by volcanic activity.

Uranium mineralization, Pine Creek Geosyncline, N.T., by John Ferguson

Recent mapping by BMR field parties and numerous exploration companies has led to a better understanding of the stratigraphy of the Pine Creek Geosyncline. Mining and detailed exploration in this area have also contributed abundant direct information on uranium deposits. This information is the basis for petrochemical studies of the origin and controls of uranium mineralization associated with the Lower Proterozoic rocks of the Pine Creek Geosyncline. During a two-month field season, extensive representative sampling of all the major rock units in the area was undertaken. Through the willing co-operation of companies ready access to drill cores was also provided, thereby allowing sampling of the uranium-mineralized zones. Major- and trace-element contents of rocks and minerals are being determined, and assessments made of isotopic values for S, O, and C.

Alkaline ultramafic rock project, by John Ferguson, R. N. England, C. M. Gardner, A. Y. Glikson, J. W. Sheraton, & K. R. Walker

On a worldwide basis it is becoming increasingly apparent that alkaline ultramafic rocks and carbonatites are closely associated in space and time. The project, started in 1975, entails a study of the distribution of ultramafic rocks within Australia combined with an understanding of the broad tectonic controls governing their emplacement and petrogenesis. A study of Upper Mantle rocks and minerals is also being undertaken, as a number of these intrusions have been rapidly emplaced, and consequently contain attendant xenolithic materials of deep-seated origin. Several of these intrusives have been sampled and studied in the field. Attention is now being focused on electron-microprobe analysis of mantle-derived minerals and the whole-rock chemistry of host and xenolithic rocks.

Tabar, Lihir, Tanga, and Feni Island Groups, Papua New Guinea, by D. J. Ellis

An electron microprobe study was carried out on representative samples of lavas from this island group as part of a wider study of the rock suite (Johnson, Wallace, & Ellis, Taylor Memorial Volume, 1976). Haüyne-, sodalite-, leucite-, analcite- and chabazite-bearing varieties have been recorded, and a study of zoning in some of these minerals has been made. Several different types of zoning occur in the haüyne phenocrysts, exemplifying either an increase or a decrease of K towards the rim. Three different substitutions are apparent: no Ca enrichment with decreasing K, and two different kinds of Ca substitution with decreasing K.

Instrument laboratories and supporting facilities, by R. N. England, G. W. R. Barnes, & R. Flossman

Electron probe microanalyzer laboratory (England, Ellis). The connection of the X-ray energy multichannel analyser to BMR's central H.P. 2100A computer for fully automated quantitative analysis is nearly complete, and storage for an adequate liquid nitrogen supply for this equipment and the new Scanning Electron Microscope due for installation in 1976 has been arranged in the precincts of BMR.

Apart from the analysis of the feldspathoidal lavas, reported above, the microprobe has been used for ad-hoc determinations, and for a project on plagioclase phenocrysts in recently erupted lavas from Karkar volcano, PNG. Chemical variation in the lavas can be explained by fractionation of plagioclase phenocrysts with a composition close to An_{75}. Analytical results gave an average composition of An_{88} for the phenocrysts. No satisfactory explanation could be found for the discrepancy, and work on the project is in abeyance.

X-ray diffraction laboratory (Barnes). About 950 samples were processed in the X-ray diffraction laboratory, of which about one-quarter were ad-hoc determinations, and the remainder mainly for the Baas Becking Laboratory, the Arunta Project, the Museum, Engineering Geology, and the Petroleum Technology Laboratory.

During the year the automatic sample loader and measuring set were installed. The system permits 35 samples to be loaded and run automatically. A motor controller carries out automatic measurement and data collection, and drives the sample loader and flat-bed recorder. A programmer is used in combination with the motor control, and can accept up to 15 programs with a maximum of 121 instructions. It is planned to equip the system with a printer or teletype, and develop a link with the BMR's central computer facility for completely automatic operation. In addition, safety shutter equipment has been installed.

Thin-section laboratory (Flossman). Eleven hundred thin sections, 40 polished thin sections, and 10 polished sections were prepared, and about 30 rocks were slabbed and polished. During the year, laboratory equipment was reorganized, and some new polishing laps, saws, a belt sander, and impregnation and cleaning equipment were installed.

GEOCHEMISTRY

The activities of the Geochemistry Group have been concerned mainly with regional geochemical exploration surveys and the chemical analysis of samples collected during these surveys.

Stream sediment sampling, sieving-out of the minus 85-mesh fraction, and the preparation of heavy-mineral concentrates have been the main field techniques, and in the laboratory atomic-absorption spectrophotometry, X-ray fluorescence analysis, and emission spectrography have been used for the analytical work.

Progress with project work is as follows:

Pollution studies in the Molonglo River, N.S.W. and A.C.T., by A. D. Haldane

Monitoring the levels of dissolved zinc, suspended zinc, electrical conductance, and pH in the Molonglo River at Burbong and in Lake Burley Griffin continued throughout the year. This work arises from the activities of the Joint Government Technical Committee on Mine Waste Pollution of the Molonglo River, and measures the level of inorganic pollution in the Lake and in the River within the A.C.T.; this pollution comes from the mine waste dumps at the abandoned Lake George Mine at Captains Flat.

The full Joint Government Technical Committee met only twice during the year. Most of its work was carried out by a sub-committee of engineers concerned with the details of the design of recommended remedial treatment techniques. This did not involve BMR.

For most of the year the total zinc concentration measured at Burbong has been 0.2-0.4 ppm, and in Lake Burley Griffin 0.1 ppm. The level of pH remained normal (6-8) except on three occasions during flooding in June, when the pH level at Burbong fell to 3. This represents a potentially serious situation where large quantities of unacceptably acidic water could enter Lake Burley Griffin if the flow in the Queanbeyan River were not simultaneously at a high level.

Monitoring of the Molonglo River within the A.C.T. is expected to continue for several years after completion of the remedial work at Captains Flat.

Geochemistry of the Tennant Creek Goldfield, N.T., by A. D. Haldane & S. E. Smith

Completion of this project has been delayed owing to deferment of atomic absorption spectrophotometric and X-ray fluorescence analyses of the ironstone samples in preference for other projects. Checking for radioactivity by gamma-ray spectrograph was extended to include all the ironstone samples (973). Some forty ironstones showed anomously high gamma-ray activity, and these are being analyzed for uranium. Smith is writing up the results of the project, and it is expected that the report will be complete by mid-1976.

Regional Stream Sediment Surveys, by A. G. Rossiter. Staff: A. G. Rossiter, J. E. Mitchell (part time), K. J. Armstrong.

Orientation studies were carried out during 1972 and 1973 in preparation for regional stream sediment surveys in the Georgetown (Qld) and Westmoreland (Qld-N.T.) regions. The main conclusions to emerge were discussed in the 1974 Annual Summary, and Records describing these parts of the program were prepared this year.

The regional stream sediment geochemical surveys undertaken by BMR are designed to assess the economic potential of a region, and to delineate broad areas where future detailed exploration should be concentrated. The program commenced in 1974, when the *FORSAYTH* (Qld) 1:100 000 Sheet area was sampled, and continued in 1975 with the completion of the *HEDLEYS CREEK* (Qld) and the adjacent *SEIGAL* (N.T.) 1:100 000 Sheet areas. Samples sieved to minus 180 microns (85 mesh BSS), as well as heavy-mineral concentrates, were collected at a sample density of about 1 sample per 2 sq km.

Georgetown area, Qld. Analysis of the sieved samples from the *FORSAYTH* 1:100 000 Sheet area began early in 1975. Atomic absorption spectrophotometric determinations for beryllium, chromium, cobalt, copper, iron, lead, lithium, manganese, nickel, silver, and zinc are available, and X-ray fluorescence analysis for arsenic, barium, bismuth, cerium, niobium, rubidium, sulphur, thorium, tin, tungsten, uranium, and yttrium should be completed early in 1976. Microscopic examination of the heavy-mineral concentrates is proceeding, and this will be followed by semi-quantitative emission spectrographic analysis. Field data and atomic absorption values have been coded in readiness for computer processing, but the interpretation phase of the project cannot begin fully until the XRF results are available.

Westmoreland area, N.T. and Qld. Analysis of the *HEDLEYS CREEK* and *SEIGAL* sieved stream sediments began only recently, and although only some 130 samples had been analysed at the time of writing, a significant anomaly has already been located. Anomalous levels of copper (maximum 118 ppm), tin (665 ppm), uranium (23 ppm), thorium (145 ppm), beryllium (11 ppm), bismuth (11 ppm), lithium (47 ppm), tungsten (19 ppm), niobium (77 ppm), and yttrium (237 ppm) occur over an area of about 15 sq km centred 3 km southeast of Norris's copper mine. For all elements except tin, these values are about twice the general background in the region. The anomaly occurs in granite (Nicholson Granite Complex) and acid volcanics (Cliffdale Volcanics), and lies close to the Calvert Fault. More detailed stream sediment and reconnaissance soil sampling were completed during the 1975 field season, but the analytical results are not yet available.

Geochemical exploration for gold, Forsayth area, Qld, by A. G. Rossiter

Soil sampling was carried out around the Big Reef and Two Micks gold mines to evaluate the usefulness of this technique in delineating gold deposits in the Forsayth area. Gold values exceeding 0.1 ppm in minus 180-micron (85-mesh BSS) soil fractions are reliable indicators of gold mineralization, but a very sensitive analytical technique is required. More easily determined, and equally as reliable as indicators of gold, are the elements bismuth (upper limit of background 5 ppm), copper (50 ppm), lead (100 ppm), and silver (1 ppm). Many additional elements including antimony, arsenic, molybdenum, selenium, tellurium, and zinc were determined, but no anomalous values were found. Spasmodic high mercury levels (up to 14 ppm) occur near the site of the old Big Reef treatment plant. Most of the anomalies delineated are related to known mineralization, but high values of gold and indicator elements found about 500 metres east of Two Micks are not associated with any abandoned workings. Although the anomaly is probably too small (less than 200 m × 40 m) to warrant further work, its discovery indicates that soil sampling does have potential for gold exploration in the Forsayth area.

A similar program was carried out at the Jubilee Plunger mine near Robin Hood homestead. Here mineralization is associated with high gold, copper, lead, silver, and zinc values in the overlying soils; no analytical data for bismuth are available. The Jubilee Plunger results have been reported in a Record (1975/68) by K. J. Armstrong.

Geochemical anomaly west of Mary Kathleen, Qld, by A. G. Rossiter

A significant copper anomaly in soils overlying calcareous siltstone of the Corella Formation was discussed in last year's *Annual Summary*. The anomaly is about 600 metres long and up to 100 metres wide. Copper values range up to 950 ppm, compared with levels of less than 60 ppm away from the anomalous zone. The work in the area has been written up as a Record (1974/182).

Cullen Granite project, N.T., by G. R. Ewers & P. A. Scott

BMR has been interested in the Cullen Granite for some time, and when it was suggested by P. W. Crohn, of the Northern Territory Geological Survey, that the granite and its relation to adjacent mineralization warrants investigation, and that BMR help would be appreciated, it was agreed to carry out an exploratory investigation of the geochemistry of the various phases of the Granite.

A total of 154 samples were collected in August and early September—114 from the various phases of the Cullen Granite, and 40 from closely associated rock bodies, viz., the Edith River Volcanics, xenoliths, adjacent country rocks, and basic dykes. The laboratory program for this project includes petrography and chemical analysis for a total of 37 major, minor, and trace elements.

Preliminary drafting of sample locality maps and some writing up are under way, but no analytical results are as yet available.

Analytical laboratories and supporting facilities, by B. I. Cruikshank. Staff: S. E. Smith, B. I. Cruikshank, J. G. Pyne, T. I. Slezak, J. C. W. Weekes, J. L. Fitzsimmons, P. J. Swan

The Chemical Laboratory provides analytical support for a number of projects undertaken by members of the Geochemical and Petrological Groups. Work carried out in the laboratory this year was associated mainly with five projects: the Georgetown geochemical survey, the Westmoreland geochemical survey, the geochemistry of the Tennant Creek Goldfield, Antarctic geochemistry, and pollution studies of the Molonglo River.

During the year the new Philips PW 1450 X-ray fluorescence spectrometer was commissioned complete with sample loader and dedicated on-line data processing. Two other instruments, the Varian AA6 atomic absorption spectrophotometer and the Hilger & Watts direct-reading optical spectrograph, were interfaced with BMR's H.P. 2100A computer for on-line data processing.

Atomic absorption laboratory. 1970 samples were analyzed (19 500 element determinations), including 1270 samples from Georgetown and 400 from Westmoreland.

Optical emission laboratory. 300 samples were analyzed (4700 element determinations)—220 by the direct-reading spectrograph and 80 by the Hilger Large Quartz Spectrograph.

X-ray fluorescence laboratory. 1040 samples were analyzed for major elements (9360 element determinations), including about 500 from Tennant Creek and about 200 from Antarctica.

Trace elements were determined on 850 samples (8500 element determinations) including 200 from Antarctica and 130 from Westmoreland. Analysis of 1160 Georgetown samples is under way; 3 of the required 18 elements have been completed (3480 element determinations).

Miscellaneous determinations. The laboratory also analyzed 230 water samples from the Molonglo River and Lake Burley Griffin, and 12 from Lake George, as well as 973 Tennant Creek ironstones for total gamma-ray activity by gamma-ray spectrometer. The radioactivity found in some of the samples was due almost entirely to uranium.

Sample preparation laboratory. Analytical work within the laboratory necessitated the preparation of about 1800 pressed pellets and 1000 fusion discs of samples for X-ray fluorescence analysis. Rock crushing and sample grinding, where necessary for X-ray fluorescence and optical emission analysis, were also undertaken. In addition, determinations of loss on ignition and preparation for mass absorption measurements were done on about 330 samples.

GEOCHRONOLOGY

STAFF: R. W. Page (on study leave since April), L. P. Black, M. W. Mahon, T. K. Zapasnik, J. L. Duggan

Introduction, by L. P. Black

Geochronological research is an important adjunct supporting BMR mapping programs. During the past year it has concentrated on six major projects in the Northern Territory and Queensland. Current progress on these projects is reported below.

A total of 1275 successful runs were carried out on the Nuclide and MS-X mass spectrometers, again a record for the year. The result is particularly gratifying in view of some down time on the mass spectrometers, and the absence of Page for about half the year.

The past year saw a general up-grading of the sample preparation area, and the establishment of a laboratory for routine mineral separation in December, 1974. However, pending alterations, the incomplete facilities in the mineral separation laboratory mean that BMR still depends on an external contractor for much of its mineral separation. During the year a total of 685 total-rock crushings and 72 mineral separations were made for geochronological work.

Arunta Block, N.T., by L. P. Black

A total of 207 mineral and rock samples were isotopically analyzed for Rb and Sr during the year. The laboratory work, which supports the mapping program, will continue through 1975-1976. Sampling was carried out this year on the Anmatjira, Wooluna, Alice Springs, and Jervois Granites, and on core from the Mud Tank (Strangways Range) carbonatite. No further sampling is planned for the 1976 season.

Current Rb-Sr isotopic data support those presented in the last *Annual Summary* and clearly indicate a complex geochronological history for the Arunta Block. Most of the previously postulated events are now documented more fully; some additional ages have also been obtained.

Most, if not all, of the granulite-facies metamorphism appears to have occurred about 1800 m.y. ago. This was followed by a regional event, of amphibolite-facies grade, at about 1700 m.y. Granite formation has occurred frequently from 1800 to 1000 m.y. It is hoped that further work will show whether or not intrusion is confined to distinct regional episodes.

It is now clear that the ultrabasic rocks of the Mordor Complex and its cross-cutting pegmatites were emplaced about 1200 m.y. ago. There is, however, some scatter in the total-rock isochron. It is hoped that current work on minerals separated from the ultrabasic rocks will indicate the cause of this scatter, and thereby the genesis of this intriguing suite of rocks. Further work on the adjacent orthogneiss has not confirmed an earlier suggestion that it may be of lowermost Proterozoic age. Rather, it seems probable that its apparent age is related to the 1700 m.y. regional metamorphism, and not to the time of its original crystallization.

Both direct and indirect attempts have been made to date the beginning of sedimentation in the Amadeus Basin. At present our most precise control is given by the work of Marjoribanks & Black (*J. geol. Soc. Aust.*, *21*, 1974, pp. 291-300), who advocate a maximum age estimate of 1080 m.y. An attempt to date a basal siltstone member of the Heavitree Quartzite itself was unsuccessful, for it yielded a widely scattered array of points on an isochron diagram. This probably results from migration of Rb and/or Sr since deposition of the siltstone. Isotopic analyses on minerals separated from a north-trending dolerite dyke are in progress to establish an additional lower limit for the deposition of the Heavitree Quartzite.

The middle Palaeozoic Alice Springs Orogeny has severely limited the usefulness of the K-Ar and Rb-Sr mineral studies in the Arunta Block because it has often partly or completely masked earlier geological events. In fact, the effects of this orogeny were of sufficient intensity to produce small bodies of aplite and pegmatite in the Huckitta Dome area of the Harts Range.

Georgetown Inlier, Queensland, by L. P. Black

The primary aim of geochronological work in the Georgetown Inlier is to support the 1:100 000 mapping program. Laboratory work on the samples collected in 1975 is likely to extend until at least the end of 1976.

During the year a total of 80 total-rock and mineral samples were isotopically analyzed for Rb and Sr, completing work on all samples collected before the 1975 field season. Neither the Forsayth and Digger Creek Granites, nor the Robin Hood Granodiorite yielded sufficient spread in Rb/Sr ratios to obtain total-rock ages. Hence these units were extensively sampled again this year. Outcrops of the Robertson River Metamorphics at Bull Creek and Stars Well (*FORSAYTH* 1:100 000 Sheet area) yielded concordant total-rock isochrons of about 1500 m.y. This is significantly younger than a Rb-Sr muscovite age of 1700 m.y. derived for the Einasleigh Metamorphics at Stockmans Crossing (*FORSAYTH* 1:100 000 Sheet area). The current thinking of field workers, however, is that these are equivalent units. Consequently, both were extensively resampled for dating this year. It is surmised that the different ages may be the result of the influence of metamorphisms resulting from successive orogenies. Further work on total-rock and mineral systems should help to resolve the problem.

Herberton/Mount Garnett area, Queensland, by L. P. Black

A total of 67 total-rock and mica analyses for Rb and Sr have essentially completed laboratory work on samples collected during 1974. The results have resolved two important points. First, the Kalunga Granodiorite has been shown to represent two different magmas emplaced about 20 m.y. apart. Secondly, work on greisenized samples from mineralized areas now clearly shows a close correlation in time between the greisenization (and presumably the association Sn and W mineralization) and the intrusion of the extensive Carboniferous-Permian granites. It is hoped that detailed analysis of the greisen ages will reveal further information on the mineralization process.

Tennant Creek area, N.T., by L. P. Black

Laboratory work on the Tennant Creek area is now at an advanced stage. The only specimens still to be analyzed are total-rock samples from the Bernborough Volcanics and mica separates from lode material from working mines and drill core. A detailed assessment of the data has been deferred until all results are available. However, it is already apparent that the bulk of the granites and porphyries yield ages in the range of 1700-1800 m.y. The so-called 'Archaean' rocks from BMR DDH No. 3, now dated at 2000 m.y., are of early Proterozoic age. There is no evidence, in the Tennant Creek area, of the overprinting by Palaeozoic tectonic events which show up in the Georgetown Inlier and the Arunta Block.

A total of 96 mineral and whole-rock samples have been analyzed in the past year in this study, which supports both geological mapping and geochemical studies.

Elcho Island project, N.T., by L. P. Black

A single glauconite specimen purportedly collected from the Wessel Group at Elcho Island over ten years ago yielded concordant K-Ar and Rb-Sr ages at about 780 m.y. This age estimate was found to conflict with the occurrence of Middle Cambrian trilobites in pebbles thought to have been derived from the same Group. Field work this year was aimed at collecting further glauconite-bearing specimens to obtain check analyses, and at searching for a locality where the fossils could be found in situ. Fossils were found in place well below high-tide level on the western side of the island. If the new glauconite analyses should confirm the original 'age', the whole question of glauconite dating may need review.

Alligator Rivers project, N.T., by R. W. Page

In the last *Annual Summary* the general age groupings of the migmatite complexes and various late acid and basic intrusions were discussed. A further 68 rocks and mineral separates were isotopically analyzed this year, the additional Rb-Sr work on the Nanambu and Nimbuwah Complexes being undertaken to check earlier conclusions. Assessment of the Nanambu Archaean and younger total-rock data reveals that the low-Rb/high-Sr rocks are more resistant to alteration, and have withstood isotopic re-equilibration during the 1800 m.y. metamorphism. However, samples with high Rb/Sr ratios are normally partly or completely updated by this 1800 m.y. event. New mica ages were also measured on some of the Nanambu gneisses known to be 2500 m.y. old from Rb-Sr total-rock isochrons. The biotite ages are internally concordant at around 1800 m.y., reflecting the well documented lower Proterozoic regional metamorphism. The muscovites are some 100 m.y. to 250 m.y. older than corresponding biotites, suggesting incomplete loss of radiogenic strontium from muscovite, and/or that Rb has been taken up by muscovite in a random manner.

Further Rb-Sr analyses of 'granitoid core' and other parts of the Nimbuwah Complex have so far not revealed any sign of an Archaean age such as that found in the Nanambu Complex. Separate isochrons for each sampling site in the Nimbuwah Complex nearly always yield an 1800-1850 m.y. age, and a relatively low initial Sr^{87}/Sr^{86} ratio of about 0.707.

Much time and effort was expended in an attempt to find the age of the Nungbalgarri Volcanic Member, part of the flat-lying Kombolgie Formation. Geological and other isotopic constraints indicate that these rocks are less than 1720 m.y. old (emplacement age of Oenpelli Dolerite), but more than 1200 m.y. (minimum K-Ar age from post-Kombolgie dyke). Duplicate Rb-Sr analyses were made on 8 different minerals (and mixtures of minerals), as well as the freshest total-rock sample available. The data show a very large scatter on the conventional isochron plot, and no unequivocal age can be interpreted. Alteration of the rock has produced partly open isotopic systems in virtually all minerals. An 'alteration event' having a maximum age of about 1050 m.y. could have produced the observed distribution of data points.

Mount Isa/Cloncurry project, Queensland, by R. W. Page

A total of 126 total rock and mineral analyses were made during the year. Efforts in Rb-Sr geochronology in this region have been concentrated on three fronts: (i) the meta-igneous rocks of the central basement (Leichhardt Metamorphics, Argylla Formation, Kalkadoon Granite); (ii) Lunch Creek Gabbro-Lakeview dolerite; (iii) Tuff Marker Beds in the Urquhart Shale (Mount Isa Group).

(i) Continued attempts to date the times of formation of the two acid volcanic suites (Leichhardt Metamorphics and Argylla Formation) of the basement succession have met with mixed success. For both the Leichhardt and Argylla rocks, separate isochrons constructed for each sampling site give quite different ages ranging from 1690 m.y. to 1840 m.y. for the Leichhardt Metamorphics, and from 1560 to 1650 m.y. for the Argylla Formation. Isochrons obtained from samples with low Rb/Sr ratios have steeper slopes, and thus give older ages than isochrons from samples with higher Rb/Sr ratios. All the isochrons so generated still have a relatively high initial Sr^{87}/Sr^{86} of 0.71 to 0.72. This, and the fact that younger 'ages' generally correspond to higher initial ratios, strongly suggest open-system behaviour of Rb and/or Sr. Thus, even the oldest ages so far obtained for the volcanic suites must still be regarded as minima. The U-Pb zircon approach is currently being used in an attempt to clarify these and other ages from the Mount Isa region.

Age relations between various phases of the Kalkadoon Granite remain unclear despite new Rb-Sr total-rock analyses from both the Prospector and Mary Kathleen 1:100 000 Sheet areas. Data points show a large scatter about the isochrons, and ages range from 1630 m.y. to 1700 m.y. Tentative indications of less disturbed isotopic systems going back to around 1830 m.y. will be tested by the U-Pb analysis of zircons from some of the rocks.

(ii) Total rocks and mineral separates from two cross-cutting basic intrusions, the Lunch Creek Gabbro and Lakeview dolerite, near Mary Kathleen were analyzed by Rb-Sr techniques. Although some isotopic discordance is evident between plagioclase, total rocks, and clinopyroxenes, consistent ages of 1500 ± 80 m.y. for the Lunch Creek Gabbro, and 1140 ± 12 m.y. for the Lakeview dolerite were obtained. These results are in accord with other known field and isotopic age relationships.

(iii) The so-called Tuff Marker Beds (TMB) are part of the Urquhart Shale, the formation in the Mount Isa Group which contains the economic mineralization. The TMB are extemely fine-grained potash-rich beds (mostly about 2 cm thick, but up to 60 cm thick) that are thought to be of tuffaceous origin. Together with the rest of the Mount Isa Group, they are regionally metamorphosed in the lower greenschist facies. The aim of the Rb-Sr study was to date the time of tuff deposition, and hence establish some firm limits for the age of the Mount Isa Group.

Five blocks (about 18 cm $\times$ 18 cm $\times$ 18 cm) of TMB whose stratigraphic positions are well known were sliced along bedding planes, and the 'beds' obtained were individually crushed and analysed. From each block a separate Rb-Sr isochron was established, but in all cases rather large errors (of about 8 per cent) are associated with the age obtained. The initial Sr^{87}/Sr^{86} ratios are generally high (up to 0.735), and vary between blocks. This, together with the fact that the 'average' TMB isochron age of about 1430 m.y. is essentially that of the well documented metamorphism known from other studies in the Mount Isa area, suggests that the TMB isochron ages are themselves related to a metamorphic imprint, and probably have no stratigraphic significance. However, it is possible to extrapolate a likely maximum age for the TMB, and hence the Mount Isa Group, by averaging the measured Rb/Sr ratios, and assuming a suitably low initial Sr^{87}/Sr^{86} composition. When this is done, a maximum age *estimate* of about 1600 m.y. is obtained.

ORE GENESIS INVESTIGATIONS

Supervising Geologist: W. M. B. ROBERTS

STAFF: W. M. B. Roberts, James Ferguson, K. Johnson (to July), D. B. Fitzsimmons

Mineralization in the Golden Dyke Formation, by W. M. B. Roberts

The purpose of this investigation is to determine, if possible, the genesis of the base-metal sulphides and the primary uranium mineralization in the Golden Dyke Formation, and to establish what were the controlling factors in the emplacement of the deposits.

During the course of the investigation attempts have been made by the Group and members of the Baas Becking Laboratory and the Sedimentary Section, together with an overseas geochemist, to provide information on some aspects of postulated mineralizing processes by carrying out various experimental studies, as indicated in following sections of this report.

The mineralogical, petrological, and chemical work has been virtually completed, and writing up is in progress. The investigation has revealed that both the sulphides and the primary uranium minerals have a hydrothermal, though not necessarily igneous, origin.

Two major types of deposit exist in the Golden Dyke Formation: a concordant, or nearly concordant, copper-lead-zinc type, represented by the Browns and Mount Bonney deposits, and a discordant lead-zinc type, of which the Woodcutters deposit is an example.

The 'concordant' deposits appear to have been emplaced early in the history of the rocks, possibly during late diagenesis or early lithification, before any major tectonism had taken place. The sulphides are accompanied by extensive wall-rock alteration resulting in the development of amphibolitic rocks consisting of tremolite-actinolite, biotite, chlorite, calcite, and dolomite, and of chlorite and andalusite schists. Subsequent folding has sheared and recrystallized the 'ores' without grossly altering their original position with respect to the sediments. Sulphur isotope and mineralogical evidence suggests a temperature of emplacement of about 200°-250°C.

The Woodcutters deposit, on the other hand, appears to have been emplaced as a direct result of tectonism. The deposit fills tension fractures resulting from the folding of the Golden Dyke rocks. It differs also from the 'concordant' type in that there is no wall-rock alteration associated with the mineralization. The veins consist essentially of dolomite and some quartz, and contain lead and zinc sulphides and lead sulpho-salts. Copper is a minor constituent. Sulphur-isotope evidence points to a much lower temperature of emplacement for this deposit than for the Browns/Mount Bonney type.

Further work is needed before conclusions can be reached about the causes of the widespread fluid movement responsible for the mineralization.

Rum Jungle Special Sheet mapping (K. Johnson)

The mapping of the Rum Jungle Special Sheet area has been completed, and the geology plotted on to bases which are being drafted. The details of the geology are presented under the section on mapping in the Pine Creek Geosyncline.

Stable isotope study, Rum Jungle area, by T. H. Donnelly (Baas Becking) & W. M. B. Roberts

Three mineral deposits are being studied:

1. Browns (lead-zinc-copper)
2. Mount Bonney (zinc-lead-copper)
3. Woodcutters (lead-zinc)

The isotopic study involved the investigation of sulphur from sulphides, carbon and oxygen from carbonates, and carbon from carbonaceous rocks. Samples have been examined from each of the above three lodes and from the Golden Dyke Formation and the Celia and Coomalie Dolomites. Although the results are still being assessed, the following general conclusions can be drawn from the sulphur isotope data.

The results of the sulphur isotope study show a similar average delta S^{34} value for both Browns and the Mount Bonney deposits, namely + 1.8, S.D. = $\pm$ 3.2 percent, and + 2.2, S.D. = $\pm$ 0.7 percent, respectively. The larger standard deviation for the Browns values is the result of including a number of sulphides from surrounding rocks. A bulk-ore analysis for Browns, excluding pyrite, gave a value of —1.9 percent. When the sulphur isotope results for Browns deposit are plotted against drill-hole depth, two relationships emerge. Pyrite plots randomly throughout the section, whereas all other sulphides plot on a smooth curve from S^{34}-enriched sulphide at the bottom of the core to S^{32}-enriched at the top.

Structurally, mineralogically, and from the sulphur isotope values, Browns and the Mount Bonney deposits are similar. The Woodcutters deposit is quite dissimilar, and the rock associations clearly show a low temperature of ore formation. Delta S^{34} values for bulk ore samples (1) excluding pyrite, and (2) including pyrite were both + 11 percent; however, when delta S^{34} is plotted against depth, the results indicate a relation between formation of galena and sphalerite, but not with pyrite. The isotopic data indicate that there has been an approach to equilibrium between the galena and sphalerite, and if we accept a co-existing pair showing the greatest isotope fractionation as possibly the nearest approach to equilibrium, then a temperature of about 150°C is indicated. The geology, mineralogy, and sulphur isotope data would appear to indicate that Woodcutters resembles a Mississippi Valley-type deposit.

Experimental investigations, by James Ferguson

Metal/carbonate interactions. The ability of calcium and magnesium carbonates to concentrate lead and zinc from the water column, and, during subsequent diagenesis, to act as metal sources for the formation of metal-rich hydrothermal brines is currently under investigation.

Initial experiments aimed at determining distribution coefficients for lead between both calcite and aragonite and co-existing solutions have required an analytical technique for the determination of trace amounts (less than 0.1 ppm) of lead in highly saline solutions. Assessment of the use of carbon-rod atomization/atomic absorption spectroscopy techniques for the purpose has shown that precise measurements are possible only under strictly defined atomization conditions, and for solutions containing less than 0.5 M NaCl and more than 0.05 ppm Pb.

Preliminary data on the removal of Pb from $Ca(HCO_3)_2$/NaCl solutions from which calcite is precipitating indicate that co-precipitation of Pb is accompanied by direct precipitation of insoluble lead species.

The presence of organic matter, both particulate and soluble, is known to influence the mineralogy and morphology of carbonate phases deposited from solution. One aspect of this influence is the ability of certain types of organic matter to induce the formation of ooids. These spherical bodies occur in both modern and ancient sediments, and if their mechanism of formation can be defined, they may serve as environmental indicators. Experimental work to date has resulted in the synthesis of aragonite and monohydrocalcite ooids, and has indicated that humic acids whose molecular weights lie in the range 20 000-50 000 are the most effective type of organic matter for inducing ooid formation.

Simulation experiments. Work on simulated sedimentary systems designed to provide information on the formation and diagenesis of calcium and magnesium carbonate phases (with B. Bubela and P. J. Davies), and the role of organic matter in the formation of abnormally high concentrations of metals in pore waters of sediments (with R. O. Hallberg and B. Bubela), has continued.

BAAS BECKING GEOBIOLOGICAL RESEARCH LABORATORY

Executive Officer: P. A. TRUDINGER (CSIRO)

STAFF: P. A. Trudinger, G. W. Skyring, I. B. Lambert, T. H. Donnelly, L. A. Chambers, C. J. Downes, D. Z.

Oehler, J. H. Oehler, M. D. Petersen (all CSIRO); W. M. B. Roberts (BMR).

SULPHUR BIOLOGY, BY G. W. SKYRING

Desulfoviridin

Desulfoviridin is a major component of the sulphate-reducing bacteria, *Desulfovibrio*; it is also the sulphite reductase of these bacteria. The laboratory has established that the chromophore of the enzyme desulfoviridin possesses part of the catalytic reactivity of the intact protein—namely the production of sulphide from dithionite. Attempts to show that the chromophore can catalyse the reduction of sulphite, the natural substrate of the enzyme, have been unsuccessful.

Further studies on the spectral and chemical properties of desulfoviridin have shown that, during preparation of purified samples, desulfoviridin is altered slightly, causing spectral changes. These spectral changes are associated with the tetrapyrrole chromophore.

Scientifically, these results are significant because they open up the prospect of a chemical and physical-chemical investigation of the mechanism of catalysis of sulphite reduction. In collaboration with Dr R. J. Porra (Division of Plant Industry, CSIRO), we have also initiated studies into some aspects of the biochemical synthesis of these tetrapyrroles. Present results suggest that *Desulfotomaculum* species possess an enzyme which inserts iron into an octacarboxylic sirohydrochlorin, but the *Desulfovibrio* species do not possess this enzyme.

All of these studies have biogeochemical implications in view of the often-expressed notion that the development of biological sulphate reduction may have been an early event in biochemical evolution. Tetrapyrroles are known to form abiologically under conditions simulating those predicted for the primordial (pre-biotic) terrestrial environment. Chemical reduction of sulphur compounds catalysed by tetrapyrroles may, therefore, represent the precursor of the biochemically-mediated reaction.

Heavy metals and sulphate reducers

Brines are thought to have been the transporting medium for bringing base metals into ore-forming sedimentary environments. We have tested the ability of nine halotolerant (17 per cent NaCl) sulphate-reducing bacteria to grow in the presence of concentrations of Pb, Cu, and Zn similar to those found in the Red Sea and Dead Sea brines, and concentrations much higher than these were also tested.

In high concentrations of phosphate (2.0 g K_2HPO_4 per litre) and organic matter (2.0 g yeast extract per litre) high tolerances at pH 7.0 were found. As the pH of the growth medium was reduced from 7.0 to 5.5, lower tolerances were found; pH 5.0 was not conducive to sulphate reduction. At pH 5.5 Cu and Zn were more toxic than Pb.

When the phosphate and organic matter were reduced one hundred fold, these metals were much more toxic. Under these growth conditions Pb, Cu, and Zn above concentrations of 2.0 ppm were toxic; concentrations of these metals in the Atlantis II Deep brine are 600, 300, and 5000 ppm, respectively. The phosphate concentration used in the latter experiments was about 4.6 ppm (P), which approximates that found in some interstitial brines of Red Sea sediments.

Conclusions from this study with respect to possible ore-forming brines are that toxicity of base metals would depend primarily on the Ph and phosphate content and availability.

Bacteriology of sulphate reducers

A computer analysis of the characteristics of 90 sulphate-reducing bacteria isolated from Australian and New Guinea environments has been completed. R and Q mode and Principal Component programs were used, and the final result was presented as a triangular plot. Bacteriologically useful groupings were derived. The results of these studies suggest that sulphate-reducing bacteria of the *Desulfovibrio* kind are probably the most important geobiologically. They are nutritionally less demanding than those of the *Desulfotomaculum* kind, and they are able to tolerate a wide range of salt concentrations. However, much more information is required before this finding can be shown to be generally true.

PRECAMBRIAN LIFE, BY D. Z. OEHLER & J. H. OEHLER

Micropalaeontology of shales and cherts in the HYC Pyritic Shale Member of the Barney Creek Formation (McArthur Group) (with R. Logan and N. J. W. Croxford, Carpentaria Exploration Co.).

The fossil assemblage within the HYC orebody includes filamentous bacteria, coccoid and filamentous blue-green algae, and possible coccoid eukaryotic algae. The assemblage is dominated by bacteria. The algae appear to have been detrital. Unlike the biotas from the Amelia and Balbirini Dolomites (also in the McArthur Group), the biota from the orebody does not represent an algal mat community. It appears that the ore sequence was deposited in relatively deep water, at least below the photic zone.

Microfossils isolated from inter-ore-bed shales are mainly coccoid unicells similar to those from the orebody cherts. Few filamentous bacteria were detected in the shale macerates, but it is unlikely that any such filaments could have survived the digestion procedures.

Most bacterial filaments in the cherts are encrusted with, or partly replaced by, fine-grained pyrite, suggesting that at least some pyrite formed contemporaneously with initial sedimentation. Evidence from petrographic textures suggests that the orebody cherts were deposited as viscous colloids, and that precipitation of some zinc and lead sulphide was coeval with the formation of these primary or early diagenetic cherts.

Micropalaeontology of the Balbirini Dolomite (McArthur Group)

Abundant and well-preserved microfossils have been detected in thin sections from seven localities. Initial observations suggest that the organic laminae in these sections were originally composed of mats of coccoid blue-green algae. There are very few examples of filamentous algae or bacteria. Many of the Balbirini fossils have sulphide minerals in their walls or within their cells; at four localities the algal fossils contain considerable amounts of sulphide.

Most fossils from the Balbirini assemblage are also common to the Amelia Dolomite biota (described by M. Muir, Imperial College, London). Each assemblage, however, contains some organisms that have not been detected in the other, and, compared with the Amelia Dolomite biota, the Balbirini population appears to include a greater percentage of one particular species, and to be somewhat less mineralized. These differences may prove useful for local biostratigraphic correlation and for assessment of the depositional environments of the Amelia and Balbirini Dolomites. Detailed analyses of the mineralization and microfossils of the Balbirini assemblage are in progress.

Irreversible contamination of Precambrian kerogen by younger organic compounds

Kerogen isolated from cherts about 1500 m.y. old from the Paradise Creek Formation (Queensland) was exposed to C^{14}-labelled hydrocarbons, amino acids, sugars, or fatty acids. Each kerogen sample was then extracted with organic solvents to remove all extractable organic compounds. Radioactivity left in the kerogen was counted, and is considered to be a measure of the irreversible contamination of the kerogen.

Fatty acids do not contaminate the kerogen at all. Sugars, amino acids, and hydrocarbons did contaminate the kerogen, but the level of contamination by these compounds was so small that their contributions to kerogen in ancient sediments would be insignificant. These results support the hypothesis that sedimentary kerogen is composed largely of organic matter deposited at the same time as the enclosing rocks, and that the carbon-isotopic composition of kerogens (such as those discussed below) would be unaffected by the small amount of post-depositional contamination potentially present.

Stable carbon isotopic composition of Archaean kerogen (with J. W. Smith, CSIRO, North Ryde, and M. J. Viljoen, Johannesburg Consolidated Investment Company Limited)

The purposes of this project are to elucidate the origins of kerogen in Archaean sediments, and to determine whether there are stratigraphic or age-related trends in isotopic composition that could be used for correlation in Archaean sediments. The background to this study was described in the 1974 Annual Summary.

Isotopic analysis of samples of chert and shale from the Yilgarn Block, W.A. (supplied by J. Hallberg, CSIRO, Perth), a stratigraphic sequence of samples from the Kalgoorlie-Kambalda area (contributed by Western Mining Corporation), samples (approximately 3800 m.y. old) from Isua, Greenland (supplied by the Geological Survey of Greenland), samples from Rhodesia, and samples (more than 3300 m.y. old) from the Swaziland Sequence of South Africa (supplied by M. J. Viljoen) is in progress. The samples from South Africa were collected to determine the effects of contact metamorphism on the isotopic composition of kerogen.

Based on carbon-isotopic data, the organic carbon in many of the kerogens from Western Australia appears to be of biological origin. Some of the W.A. kerogens and those from one Greenland sample, however, have isotopic compositions unlike that of younger organic matter of assured biological origin. These unusual isotopic compositions may reflect metamorphic alteration, but they may also indicate that the organic matter is of abiological origin (similar to that in carbonaceous meteorites), or that it is of magmatic origin. Data from the stratigraphically controlled suite from the Kalgoorlie-Kambalda area indicate isotopic trends that could be useful for local correlations. Final interpretations, however, depend on isotopic results from the South African suite collected to study possible metamorphic alteration of carbon-isotopic composition.

STABLE ISOTOPE STUDIES

Isotope geochemistry

Rum Jungle study (T. H. Donnelly & W. M. B. Roberts). See page 107.

Deep Sea Drilling Project (P. J. Cook, P. A. Trudinger, L. A. Chambers & T. H. Donnelly). See page 30.

Reconnaissance study of sulphur isotopes in Archaean rocks (I. B. Lambert & T. H. Donnelly). A reconnaissance study was recently commenced of sulphur-isotope ratios of sulphide minerals in Archaean igneous and sedimentary rocks from the Yilgarn craton, Western Australia. This is being carried out in collaboration with J. Hallberg and R. Hudson (CSIRO, Perth). The aims are to look for evidence of bacterial sulphate reduction in sediments, and to assess the isotopic data from the Ni ores.

Experimental studies

Physical phenomena (M. D. Petersen, T. H. Donnelly, L. A. Chambers, & P. A. Trudinger). The distribution of stable sulphur isotopes provides one means of determining whether or not diagenetic processes have taken place within sediments. It is generally assumed that, in sediments at low temperatures, bacterial sulphate reduction is the major process which determines the isotopic patterns, and indeed such patterns are often used to evaluate the course of bacterial reduction in sediments.

In order to assess possible complications introduced by physical factors we are studying the isotopic effects associated with ion-exchange and diffusion, two important processes which modify the distribution of elements in sediments.

In one series of experiments Na_2SO_4 solutions were equilibrated with quaternary ammonium ion-exchange resins in the presence and absence of NaCl. The isotopic compositions of sulphate in solution, and sorbed onto the resin, were determined. In the second series, $CuSO_4$ was diffused through about one metre of Sephadex gel, and analyses were made on the sulphate from the leading edge, middle, and trailing edge of the eluted band.

In no instance was a fractionation effect of more than 1-2 per thousand observed, and we conclude that, at least as far as sulphate is concerned, ion-exchange and diffusion are unlikely to have major effects on the sulphur isotopic distribution in sediments.

The role of sorption on solid particles in isotope fractionation was studied by reacting various concentrations of sulphate (20-400 ppm) with ground silica and bentonitic clay. In both instances fractionation (up to 3 per thousand) was observed, and there was evidence of an isotopic exchange equilibrium due to the reversible sorption of sulphate on clay. Preliminary experiments with a quaternary ammonium resin indicate that ion exchange is probably not an important factor in determining the isotopic compositon of sulphate.

Reduction of sulphate by chromous ions and isotopic fractionation (C. J. Downes & T. H. Donnelly). A value of about 22 per thousand for the isotopic discrimination between sulphide and sulphate has for some time been accepted as representing the kinetic isotopic effect associated with the chemical reduction of sulphate. This value was based on experiments using hypophosphorous acid as a reductant. We have examined the isotopic effects associated with reduction of sulphate by chromous ions in the presence of halides. Fractionations ranged from about 10 to 19 per thousand, and were correlated with the halide used in the decreasing order iodide-bromide-chloride. The systems used do not represent those found in natural environments, but the results clearly show that the isotopic effects depend strongly on the composition of the reaction medium. No single value can therefore be assigned for the kinetic isotopic effect in chemical sulphate reduction.

Sulphur pathway studies (L. A. Chambers & P. A. Trudinger). It has been proposed that very high fractionation of sulphur isotopes during bacterial sulphate reduction could result from the co-operative effects of multiple intermediate steps in the pathway. The Laboratory had previously questioned the validity of thiosulphate and trithionate as true intermediates on the basis of enzyme studies, and we have now shown with growing cells of *Desulfovibrio* species that thiosulphate is not a true intermediate, and as the metabolism of trithionate leads to thiosulphate, it is also unlikely to be in the biochemical pathway.

ABIOLOGICAL SULPHATE REDUCTION, BY L. A. CHAMBERS, P. A. TRUDINGER & D. T. RICKARD (UNIVERSITY OF STOCKHOLM)

In the previous *Annual Summary* it was noted that no massive abiological production of S^{35} hydrogen sulphide occurred, but that some 'volatile' labelled sulphur species was produced. Attempts to identify this were unsuccessful, and it is impossible to say whether or not 'volatile' sulphur represents some reduction because: (a) Maximum production of 'volatile' sulphur was about 1 in 10^5 of the S^{35} used: radiochemical purity of sulphate is guaranteed only to about 1 in 10^2; (b) The results are not reproducible, and, in view of the very low 'conversions', we cannot eliminate the possibility that 'volatile' sulphur was not sulphate carried over as aerosol; (c) There is a lack of observable trends with increasing time and changes in conditions.

GEOCHEMICAL-PETROLOGICAL INVESTIGATIONS, BY I. B. LAMBERT & M. D. PETERSEN

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 New South Wales. 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 distribution 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. Relatively unaltered volcanics in these areas may also provide information concerning Ordovician-Silurian plate tectonics in southeastern New South Wales.

Woodlawn area

Chemical, X-ray diffraction, and microscopic investigations have been completed on 213 samples collected at various distances up to about 1 km from the Woodlawn orebody. A confidential report listing these data has been prepared for Jododex. Analyses of a further 73 samples are still in progress.

Around the orebody there is an extensive zone of silicification, chloritization, sericitization, and stringer mineralization in which feldspars and primary ferromagnesian minerals are virtually absent (except in some basic rocks).

The general chemical changes exhibited by felsic volcanics in this hydrothermal alteration zone include addition of Si*, Mg*, Mn, Al, K, Ag*, Cd, Zn*, Pb*, Cu*, Li, Rb, and Sn*, and depletion of Na*, Ca* and V (the elements asterisked show the clearest trends).

The black shales near the ore have slightly different trends in that they tend to be enriched also in Ti and P, but are depleted, rather than enriched, in Si.

The most significant element-ratio trend in the alteration halo around the ore is shown by K/Na which exceeds 15 (mostly between 30 and 70) through the major part of the zone, and decreases to much less than 15 in the relatively little-altered rocks. The ratio non-pyritic Fe/total-rock Mg also displays a fairly distinct trend. It is generally less than 1 in the vicinity of mineralization, but increases to mainly greater than 1 in outer parts of the alteration zone, and in unaltered rocks.

The Woodlawn orebody appears to be similar to the Kuroko deposits in a number of important respects. The available data appear consistent with accumulation of metalliferous muds in a depression on the sea-floor from ore solutions released as a result of explosive volcanic activity. These ore solutions could well have had a magmatic component which was added to metal-poor hydrothermal solutions (probably essentially seawater modified by circulation in the volcanic pile). These solutions were responsible for hydrothermal alteration of the country rocks, and therefore must have been present in the area for some time before and after the 'tapping' of the metal-rich fluids.

The petrographic, mineralogical, and geochemical features outlined here should be applicable in a general way to exploration for similar deposits in southeastern New South Wales.

Orange area

Chemical analyses have been completed on 61 samples from the vicinities of mineralization at Mount Lindsay, Calula, Lewis Ponds, and Mount Bulga. Assessment of these data and microscopic examinations have not yet been completed.

Captains Flat area

Geochemical and petrological investigations were recently commenced on 34 samples collected from drill cores through the same stratigraphic interval as the worked-out Captains Flat ore body, but at distances up to about 20 km from it.

OVERSEAS VISITS

B. Bubela (CSIRO)

Most of the time covered by this report was spent overseas. The purpose of the overseas trip was: (1) Investigation of microbiological production of methane and hydrogen from waste material having potential as an energy source; (2) Discussion of geobiological topics with workers overseas.

The work on the production of methane and hydrogen resulted in the construction of a continuous production apparatus for the process, and the evaluation of the suitability of a number of substrates for the microbiological activity. The work was done at the University of California, Los Angeles. Other institutions visited in association with this project were the University of Southern California, Stanford University, the University of Mexico, and the University of Cardiff.

The following topics were discussed at the institutions listed:

Microbiological pre-treatment of oil-bearing shales prior to extraction processes (University of Southern California). A partial microbiological oxidation of metal sulphides present in oil-bearing shales was claimed to result in increases of up to 40 percent in hydrocarbons recovered by extraction processes. An extract of a pretreated shale sample, obtained from the University of Southern California by Dr J. D. Saxby, CSIRO, and a gas chromatography analysis of the shale, showed a considerable yield increase but no significant change in the composition of the extract.

The role of organic material in sediments (University of California). Triterpenes found in sediments may be used as indicators in palaeoclimatological investigations.

Organo-metal complexes (University of Stockholm; University of Bristol). Organo-metal complexes possibly play an active role in metal accumulation and transport in sediments. Work begun at the Baas Becking Laboratory in co-operation with Dr R. O. Hallberg, University of Stockholm, resulted in a simple mathematical treatment of idealized conditions leading to preferential metal accumulation in sediments.

Toxicity of heavy metals to microorganisms (University of New Hampshire). Heavy metals may influence the biochemistry, physiology, and morphology of microorganisms. Results obtained by overseas workers agree with work done in our Laboratory.

Carbonates (University of Heidelberg, Rensselaer Polytechnic Institute, Purdue University, University of Uppsala). Carbonates, organic material, and heavy metals are frequently associated in sediment. Carbonate particles are sometimes used as indices in sedimentary environments. Carbonate diagenesis is apparently influenced by organic material.

The following meetings were attended, and papers presented:

2nd International Symposium of Environmental Biogeochemistry, Hamilton, Canada.

3rd Nordic Meeting on Chemistry and Sedimentology of the Baltic Sea, Goteborg, Sweden.

Royal Swedish Academy of Sciences, Committee for Environmental Studies, Stockholm.

Lectures were given, by invitation, at the University of California at Los Angeles, University of Southern California, Stanford University, National Aeronautics and Space Administration (NASA), University of Mexico, Purdûe University, University of New Hampshire, University of Stockholm, University of Goteborg, University of Uppsala, University of Heidelberg, and the University of Bristol.

L. A. Chambers

L. A. Chambers attended the 2nd International Symposium on Environmental Biogeochemistry in Ontario, Canada. The range of topics was programmed in four sessions:

(i) Dynamics and Biotransformations of Phosphorus, Sulfur and Nitrogen in Ecosystems.
(ii) Effects of Man on the Carbon Cycle.
(iii) Transformations of Metals within Ecosystems.
(iv) Ecosystem Studies of Element, Energy and Mass Balances.

Data presented included much valuable information relevant to metal complexing and biological cycling within a euxinic sedimentary basin.

She also visited organizations in:

(i) Los Angeles, California, U.S.A.; Bloomington, Indiana, U.S.A.; Calgary, Alberta, Canada; and Stockholm, Sweden, for discussions on geochemical topics, including stable isotope distribution and discrimination.
(ii) Coventry, U.K.; and Marseilles, France, for discussions on biochemical sulphur transformations.
(iii) Winsford, U.K., for a short familiarization course, with the manufacturers, on the *Micromass 602C*, a dual-collection ratio mass spectrometer.

Lectures were given, by invitation, at the University of California, University of Stockholm, University of Uppsala, and the Microbiological Institute, Stockholm.

FIELD TRIPS

Bacterial sulphate reduction on Lizard Island coral reef

G. W. Skyring assessed the extent and significance of sulphate reduction in the reef sediments. During this expedition three aspects were investigated: (i) the distribution of sulphate-reducing bacteria; (ii) the distribution of sulphide in the sediments; and (iii) the rate of sulphate reduction in the sediments.

The sulphate-reducing bacteria were ubiquitous, and relatively high populations were found in all sediments sampled. Sulphide was found only in sediments deposited in quiescent conditions, and it was there in an immobilized form, probably as FeS. An in-situ estimate of the sulphate reduction rate (21 mg S = M^{-2} day $^{-1}$) was similar to that found in other saline sediments. Rate potentials on the basis of radioactive S^{35} studies are nearing completion. There is a dearth of information on sulphate reduction in reef sediments, so this estimate is a useful contribution.

These results are pertinent to primary productivity measurements and estimates of ammonium in the sediments made by Dr J. Caperon (University of Hawaii).

It was found that weathered material from the granite of Lizard Island contributed to the lagoon sediments.

REVIEW

Survey of experimental geomicrobiology in Australia (P. A. Trudinger)

A survey has been made of Australian studies on, or related to, microbiological factors in mineral genesis, with particular reference to sulphides, carbonates, and metal-organic inter-relationships. The survey provides the basis for a review on 'Experimental Geomicrobiology in Australia' for a special issue of *Earth Science Reviews* to be published in connection with the International Geological Congress, Sydney, 1976.

GEOLOGICAL SERVICES SECTION

Officer-in-charge: E. K. CARTER

GENERAL

BY E. K. CARTER

During the year the organization and staff numbers in the Section remained virtually unchanged. As the year progressed members of the Section became increasingly involved in preparations for the forthcoming 25th International Geological Congress through preparation of publications planned to be available at the Congress or for the Congress, including excursion guide books, planning of sessions and excursions, and arranging of displays. Contributions were also made to the 46th ANZAAS Congress, held in January.

The Engineering Geology group, in conjunction with the Engineering Geophysics group, maintained a high level of activity with three major projects under construction, the design investigation of another, further urban development studies, and a large number of other project investigations. The holdings by the Museum of display material were enhanced considerably by the acquisition of two major mineral collections, gold specimens, meteorites, and australites. Fair drawing of the 1:2 500 000-scale geological map of Australia and supporting maps, and a revision of the standard geological symbols booklef, are in progress.

Training has been an important part of the Section's activities through the year.

The Section Leader was secretary to the Chief Government Geologists' Conference held in Canberra in May. He also participated in two inter-departmental study groups, one inter-governmental committee, and several departmental and BMR committees. He carried out the functions of Convener of the Stratigraphic Nomenclature Committee, and contributed to a history of the Bureau.

ENGINEERING AND ENVIRONMENTAL GEOLOGY

STAFF: E. G. Wilson, G. Jacobson, D. C. Purcell, J. M. M. Furstner (from January), G. A. M. Henderson, P. D. Hohnen, P. H. Vandenbroek, P. A. Lang, G. R. Anderson (until January), G. Briscoe, R. Goldsmith.
Technical Officer: J. R. Kellett; Technical Assistant: A. W. Schuett. Six to eight field hands.

CANBERRA DAM PROJECTS,

BY J. M. M. FURSTNER, D. C. PURCELL & R. GOLDSMITH

Tuggeranong Lake Dam

A diamond-drilling program was completed by the Department of Housing and Construction (DHC) at the site of the proposed dam on Tuggeranong Creek. The core was logged and the results of the investigation were reported in Record 1975/55. A large defect zone indicated at the surface was not intercepted at depth along the dam axis. Rock quality at the spillway site was proved to be good below 16 m.

Since the investigation, the dam axis has been moved 50 m downstream as a result of design changes and not geological conditions.

Googong Dam

Geological services are being provided during the construction of the 58-m-high

Googong dam which commenced in April 1975. Excavation for the diversion tunnel, 220 m long, was completed in October; support in the tunnel was provided by two steel sets at each portal, and by rock bolts as required elsewhere. Some rock bolts were set in the open-cut approaches to both portals. Construction of the access road and stripping of the overburden from the dam foundation and spillway are in progress.

Canberra's next water storage

Preliminary investigations began of several alternative water supply schemes to supply Canberra after 1985. Two possible damsites on the Gudgenby River were inspected, and office studies were carried out on a number of other damsites.

SEWER LINES AND WATER MAINS, BY D. C. PURCELL, P. A. LANG & R. GOLDSMITH

Engineering geological services were provided to DHC for investigation and construction of the A.C.T. sewerage system. The location of the sewerage works is shown in Figure GS1. The stratigraphic sequence in the volcanics to the west of Canberra has been established as a result of tunnel mapping.

Tuggeranong Sewer Tunnel

Construction continued throughout the year. Concrete lining, backfill grouting, and pressure grouting of the tunnel and shafts was completed by the end of the year. Flaws in the concrete lining were in the form of regular contraction cracks, open up to 2 or 3 mm, and honeycombed concrete near the shoulders (springline). These flaws in the lining resulted in groundwater inflows into the tunnel being greater than allowed for in the tunnel design. Subsequent pressure grouting, aimed at those geological defects making water as well as honeycombed sections of the concrete, enabled inflows to be kept well below the maximum allowable (1 cusec or 100 m^3/hr).

Studies of the effect of the tunnel on groundwater levels, based on observation bores and water inflow into the tunnel, are in progress.

Molonglo Valley Interceptor Sewer

Construction of Ryan and Pine Ridge tunnels and the connecting pipeline section was nearing completion at the end of the year.

Excavation of Ryan tunnel was completed early in the year and concrete lining of the tunnel began in August. The overall rock quality in Ryan tunnel was not as good as in Pine Ridge tunnel, due to intersection of a greater number of faults and lenses of weathered and fractured sedimentary rocks. Compared with Tuggeranong tunnel, water inflows were negligible. Correlation between expected conditions as given in the design report and actual construction conditions were good; seismic refraction profiling and rock condition correlations were excellent.

Ginninderra Sewer Tunnel

The proposed tunnel will extend from the existing Belconnen Pollution Control Centre near Ginninderra Creek, to the Lower Molonglo Water Quality Control Centre near the confluence of the Molonglo and Murrumbidgee Rivers. The tunnel will be 5 km long and have an internal lined diameter of 2130 mm.

Tenders are expected to be called in December and construction to commence late in 1976. A geological report by BMR will be included in the Information for Tenderers document.

Geological mapping of the route was carried out at a scale of 1:2500. A continuous seismic refraction survey was carried out along the route by the Engineering Geophysics group; several cross-traverses were completed in an attempt to accurately locate several faults. From April to October 14 diamond-drill holes totalling 650 m were drilled by DHC using three drill rigs; in addition, 9 groundwater observation bores were drilled by BMR. Uniaxial compressive strength, S.G., Shore hardness and point load tests were carried out on drill core samples.

Tunnelling conditions are expected to be generally good and only 12 to 15 per cent of the tunnel is expected to require support. The tunnel will be driven through dacite, rhyodacite, rhyolite, granite, shale, and sandstone. In some sections of tunnel the rock is expected to be extensively faulted and sheared, necessitating steel-set and timber-lagging support. Groundwater inflows are not expected to be large enough to cause cessation of work at any time.

Lanyon Trunk Sewer

A preliminary investigation was under-

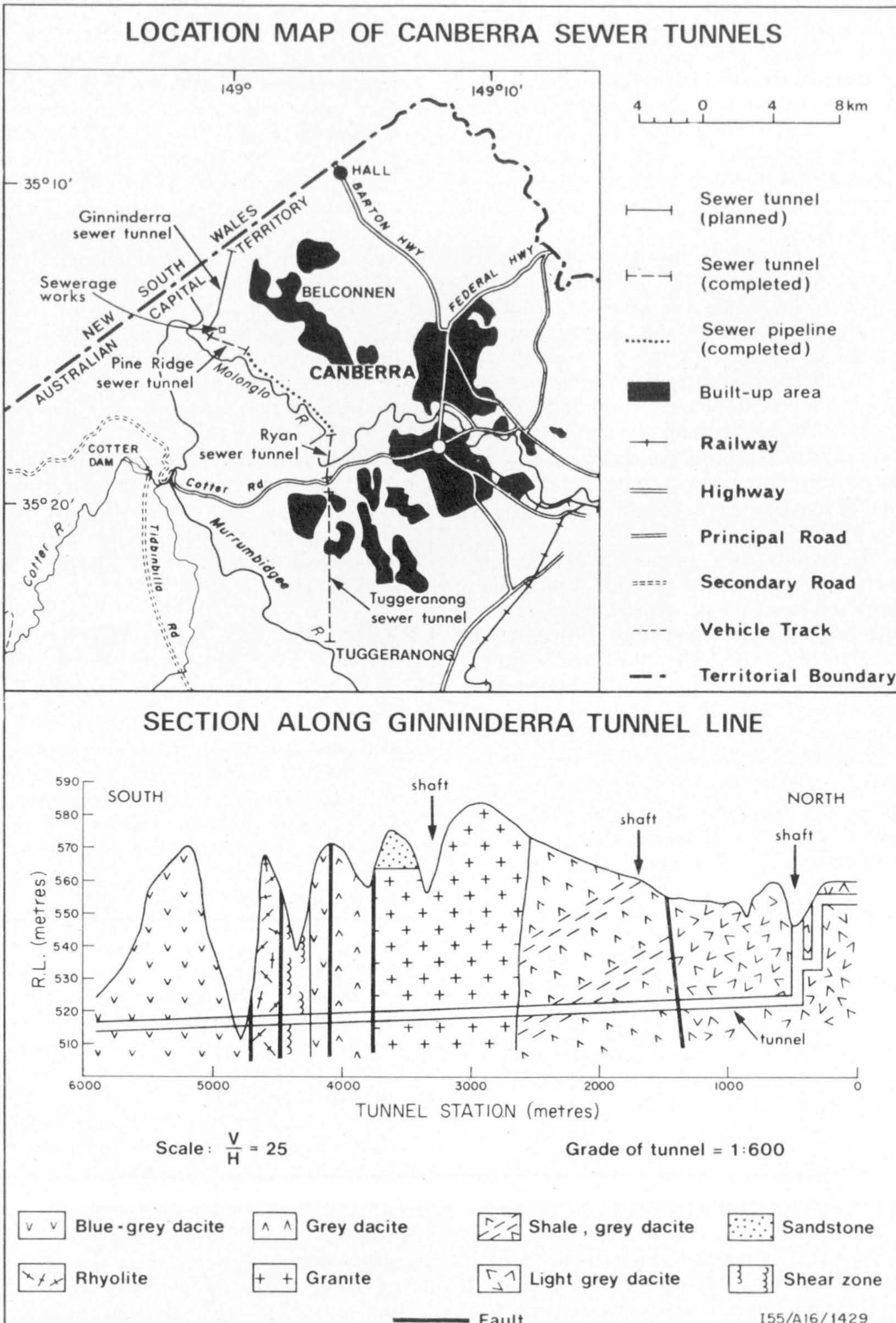

Figure GS1 Canberra sewer tunnels

taken for a 17.8-km-long sewer line along the east bank of the Murrumbidgee River in Tuggeranong. The sewer will consist of a buried pipeline ranging in diameter from 1800 mm at Tuggeranong tunnel inlet portal in the north, to 600 mm at Lanyon in the south. Average depth to pipeline invert is 2-3 m below ground surface with some deep sections of cut up to 11 m.

The route passes through Silurian dacitic tuffs and porphyry with sections of porphyritic rhyolite, shale and sandstone south of Point Hut and chert, tuff, and agglomerate near Pine Island.

As alternatives to some pipeline sections, short tunnels have been proposed. A proposed 1300-m-long tunnel south of Point Hut would be in weathered closely fractured shale. A further alternative, to tunnel completely in dacite immediately to the east, was suggested by BMR.

Three alternative tunnel routes were proposed near Pine Island with a maximum overburden of 20 m. Tunnelling conditions are predicted to be generally poor in highly weathered dacite. The most likely tunnel alternative is 670 m long through dacite and some chert and agglomerate. Support required is expected to be near 100 per cent.

A feasibility report has been prepared for DHC (BMR Record in prep); seismic profiling and diamond-drilling along proposed tunnel sections have been recommended.

Canberra City Sewerage Scheme

A portion of the city sewerage system was augmented by construction of a buried sewer pipeline through the city area. During construction the excavations were mapped to provide a record of the subsurface geology in the city. The route passed through mudstone and shale of the Canberra Group from west of Sullivans Creek to Rudd Street; most of the remainder of the route to Ballumbir Street passed through river gravels up to 4 m thick. The gravel is extensive over much of the city area and is probably related to the Fyshwick Gravels.

Pipe-jacking was used under Northbourne Avenue for 90 m. Difficulty was encountered in the gravel unit by the auger and the pipe jack.

A report on the findings was prepared.

Stromlo-Higgins Bulk-Supply Water Main

A preliminary report on the pipeline route was prepared for DHC (Record 1975/75). The route consists of 10 km of buried pipeline to a maximum depth of 3 m and a 275-m-long tunnel under Mount Stromlo. The pipeline is to supply water from the Stromlo water treatment plant to the Belconnen area.

The tunnel will be driven in porphyritic dacite and it will have a maximum cover of 16 m; at least 70 per cent of the tunnel is expected to require support. A diamond-drill hole indicated hard and strong dacite at 9 m in the central section of the tunnel line, 7 m shallower than the bedrock refractor of a seismic survey. A report on the tunnel was prepared (Record 1975/62).

The pipeline section will cross the Winslade Fault at 3400 m after passing through rhyodacite, sandstone, and pyroclastics overlain by blue-grey dacite. North of the fault the route passes through purple and green dacite as far as the Higgins reservoir.

URBAN GEOLOGY, A.C.T. AND ENVIRONS, BY G. BRISCOE, G. A. M. HENDERSON, P. D. HOHNEN, G. JACOBSON & J R. KELLETT

Geological studies of urban development areas in the A.C.T. and environs were undertaken for the National Capital Development Commission (NCDC). The locations of the main study areas are shown in Figure GS2.

Inner Canberra Redevelopment Study

Maps and notes on geological factors relevant to the proposed redevelopment of areas of inner Canberra were prepared for NCDC planners. The main geological constraints relate to poor foundation conditions in areas of limestone or deeply weathered rocks in fault zones, and to groundwater seepage problems.

Advice was also given to NCDC on geological conditions at a number of building sites in inner Canberra.

Queanbeyan-Canberra Interaction Study

A broad study of the engineering geology of Queanbeyan and environs was completed during 1975. The work involved the compilation of previous geological information, supplemented by airphoto interpretation and limited field mapping. Maps showing the

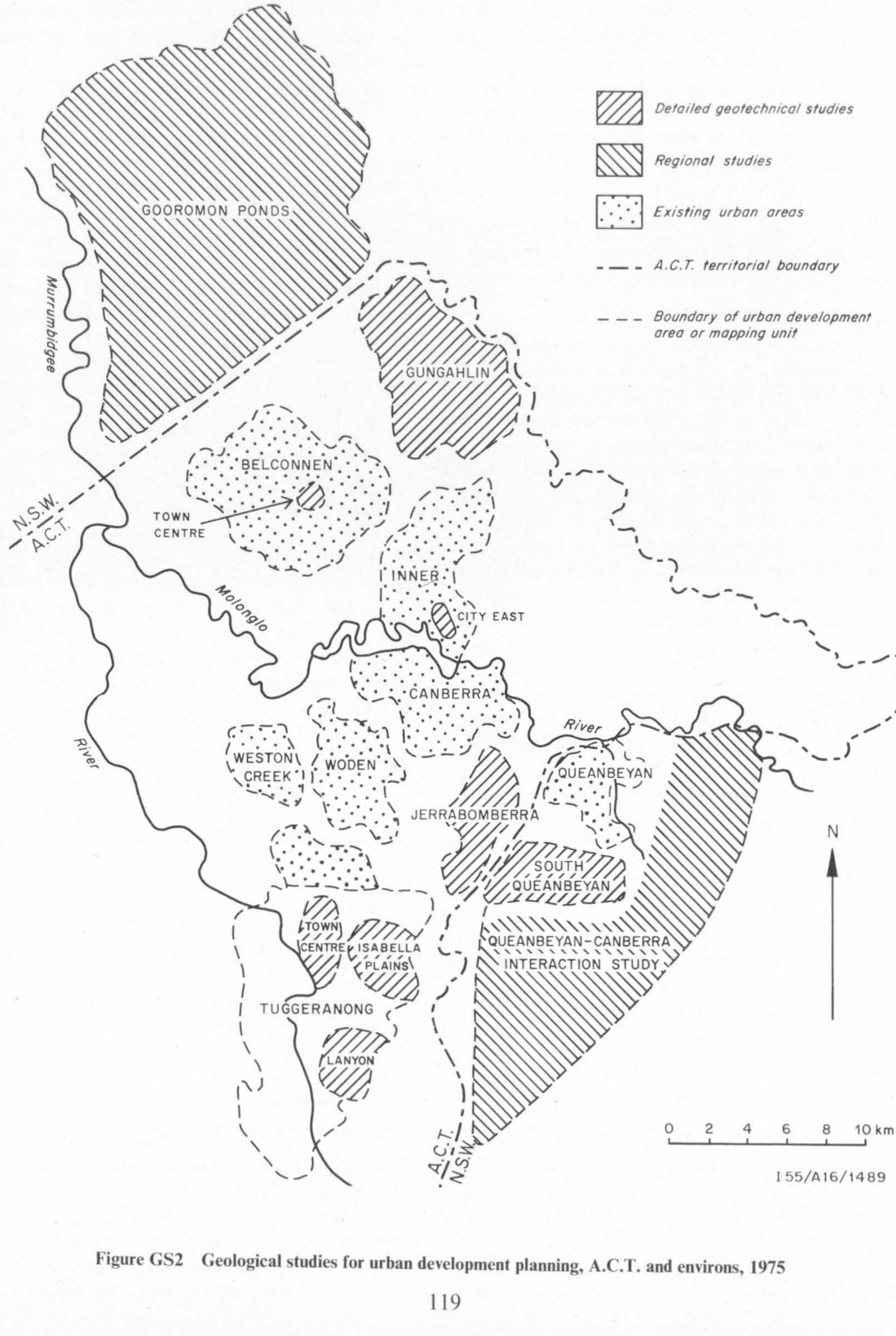

Figure GS2 Geological studies for urban development planning, A.C.T. and environs, 1975

bedrock geology, surficial deposits, resources, and geological constraints on planning decisions were prepared at 1:50 000 scale. More detailed field investigation, including a drilling program, was undertaken within the Queanbeyan City area; a separate geological and soils map was produced at 1:25 000 scale. Detailed soils mapping was carried out on Mount Jerrabomberra where unstable colluvial soils occur.

Woden-Weston Creek

Further revisions were made to a report on the geology of Woden-Weston Creek which is being produced as Record 1975/54.

Belconnen

Detailed geological investigation of the Belconnen Town Centre was undertaken to ascertain the subsurface conditions at a number of building sites. Five seismic traverses (by the Engineering Geophysics group) and five diamond-drill holes were used to investigate the sites, which are planned for high-rise development. The seismic results indicated a wide (12-50 m) linear zone of low seismic velocity, the Deakin Fault Zone, passing near or through the building sites. Subsequent drilling found that the zone is of very closely fractured rock which is highly to moderately weathered down to 20 m below surface.

A detailed investigation of the neighbouring suburb of McKellar was also undertaken in order to provide geological information for planning (Record 1975/148). A number of auger holes were drilled to evaluate foundation conditions.

A geological report on the developing suburbs of northwest Belconnen was compiled.

Tuggeranong

A report on the geology for development planning of the new town of Tuggeranong was compiled (Record 1975/93). Geological investigations in Tuggeranong during the year were mainly concerned with drainage problem areas and sewer lines.

A test bore at Freshford, west of the Murrumbidgee River, was drilled to a depth of 45 m close to the intersection of the Murrumbidgee Fault and a zone of lineaments. Groundwater was pumped at 0.35 m^3/h from closely fractured volcanics. The standing water level was about 11 m below ground surface a few days after air-lifting was completed.

A map was prepared for NCDC's consultants at short notice showing geological and hydrological factors that may influence urban design.

The geology of numerous alternative reservoir sites was reported on, and conclusions were supported by later seismic refraction data.

A brief report was prepared for the reservoir design engineers and town planning consultants on the seismic risk of the area.

Detailed seismic refraction surveys by the Engineering Geophysics group of large areas of poorly drained alluvium were in progress in late 1975.

Gungahlin

Engineering geology investigations commenced for the proposed town centre and for the first residential area. Seismic refraction traverses have shown deep weathering to be associated with previously mapped faults. Elsewhere, foundation conditions appear to be quite favourable for high-rise buildings, though individual structures will still require site investigation. Groundwater levels have been sufficiently low to predict that in the town centre serious drainage problems will not be encountered in foundation excavations.

Seismic refraction surveys were carried out by the Engineering Geophysics group in northwest Gungahlin to obtain further data on the ease of excavation of large areas of outcropping shale.

Gooromon Ponds, N.S.W.

The preliminary engineering geology notes and maps, prepared for NCDC in 1974, were revised for the BMR Record series (1975/111). Notes on stratigraphy and structure were written and additional thin sections of the acid volcanics and intrusives were described.

FOUNDATION INVESTIGATIONS, A.C.T., BY R. GOLDSMITH & G. A. M. HENDERSON

Building foundation investigations

Geological conditions were evaluated at several sites in Canberra where major buildings of national importance are planned.

Two diamond-drill holes were put down on

Section 4, Parkes; one hole encountered dacite overlying calcareous mudstone and the other intersected mudstone with limestone at depth.

Limestone was also encountered in drilling at Section 3, Parkes, and is a significant constraint on design, as difficult foundation conditions are likely.

Three diamond-drill holes were put down on Section 5, Campbell; one hole, on the eastern side of the area, encountered siltstone and mudstone suitable for foundations below 5.3 m of alluvium; water flowed to the surface from an aquifer at 25 m and indicates possible drainage problems in excavations. The other two holes, on the western side of the area, encountered deeply weathered dacite, tuff, tuffaceous sandstone, and shale.

Two sites in Yarralumla were also investigated.

Murrumbidgee Bridge No. 3

An investigation was carried out for NCDC at the site for the first major bridge across the Murrumbidgee River in Tuggeranong. A seismic survey was completed by the Engineering Geophysics group and a geological map of the site compiled. The rock at the site is grey dacite, sheared in places but providing good foundations at most pier sites. A report was prepared jointly with Engineering Geophysics for NCDC.

HYDROLOGY AND DRAINAGE INVESTIGATIONS, BY P. D. HOHNEN, G. JACOBSON & J. R. KELLETT

A.C.T. Observation Bore Network

Routine monitoring of water levels in about 70 observation bores in the A.C.T. network continued throughout the year.

The network records seasonal fluctuations of the water-table, assisting the evaluation of groundwater resources and the prediction of effects of groundwater on engineering works. Groundwater records are carded for computer storage. Record 1975/45 lists borehole information to the end of 1974.

Lake George

Monitoring of the level and salinity of Lake George, N.S.W., continued throughout the year. The lake rose to a level of 3.08 m at the end of October, its highest level since the end of 1966. Present salinity is well within the range acceptable to stock.

Jervis Bay groundwater

Monitoring of piezometers at Jervis Bay continued in an attempt to ascertain leakage paths of water from Lake Windermere, the surface of which is at an historically high level. Preliminary analysis of the results indicates that the main leakage path is to the west.

Isabella Plains drainage

Monitoring of piezometers continued in the drainage problem areas of Isabella Plains, in the developing new town of Tuggeranong. The effects of preliminary drainage construction were analysed; much of the area has been successfully dewatered.

Lanyon drainage

Following recommendations from BMR in 1974, additional augering was carried out by contractors during January and February. Forty holes were drilled and thirty of these were equipped with piezometers. Weekly monitoring of the bores continued throughout the year, and print-outs of water levels were sent to the consulting engineers at regular intervals. A report on the investigation has been prepared.

Red Hill drainage problem

A bore was sited by BMR and drilled by a contractor within a serious drainage problem area. The stability of the foundations of at least two houses was in jeopardy and access to the houses very difficult. The bore proved to be artesian, confirming that the drainage problem was due to excessive groundwater pressures. The bore was pump-tested at up to 13 m^3/h and the effect on soil-water pressures was monitored in 10 shallow piezometers. The results of the pumping test were analysed and specifications prepared for the installation of a permanent electric submersible pump. Within 24 hours of starting up the permanent installation, water levels in piezometers in three blocks fell appreciably, most by about 1 m. The piezometers continue to be monitored until sufficient data are available to design the final automatic switching positions.

Cook drainage problem

BMR was requested by the Department of Education to investigate a poorly drained area at Cook Primary School. Seven auger holes were drilled through soil materials to rock. Five holes intersected aquifers and these were pump-tested to determine their hydraulic conductivities. The Department of Education was advised on the recommended type, depths, and location of drains to overcome the drainage problem.

Water-well siting

Three additional bore sites were pegged at the National Fitness Camp site at Paddys River. These are to be drilled as necessary to augment the supply of 1 m^3/h obtained from BMR's test bore. Advice was given to NCDC consultants for the project on groundwater quality at the site. Bores were sited for domestic water supplies at two rural locations.

CONSTRUCTION MATERIALS, BY G. JACOBSON & P. H. VANDENBROEK

Sand and gravel resources, Canberra region

A broad review of the sand and gravel resources in the A.C.T. and environs was undertaken by P. H. Vandenbroek. Literature was reviewed, an airphoto study undertaken, and an aerial inspection made. A large number of deposits were visited. Recommendations for NCDC are being formulated on resource assessment and future utilization.

Paddys River gravel deposits, A.C.T.

At the request of the Department of the Capital Territory, an investigation was made by G. Briscoe of several possible gravel pits in weathered granite at Paddys River. The investigation included backhoe pitting, sampling and testing, and the assessment of reserves.

Captains Flat quarry site, N.S.W.

In collaboration with the Public Works Department of N.S.W. an investigation was made of a quarry site at Captains Flat, to be used as a source of rock-fill for the reclamation and stabilization of tailings dumps at Lake George mines. The investigation included diamond-drilling and the assessment of reserves (Record 1975/57).

Gungahlin brick shale, A.C.T.

Geological mapping and augering of a brick-shale deposit at Gungahlin were carried out by G. R. Anderson for Commonwealth Brickworks. Laboratory testing of the material and test firing indicated its suitability. Sufficient reserves are available. Results are reported in Record 1975/22.

Quarry compensation claims, A.C.T.

Inspections were made of several possible quarry sites on resumed land in the south of the A.C.T., and advice was given to the Deputy Crown Solicitor's Office in connexion with compensation claims.

CANBERRA GEOLOGY AND SERIES MAPS, BY G. A. M. HENDERSON

Correlation of the volcanics of the region

Twenty volcanic rock samples from localities ranging from Gooromon Ponds to Tuggeranong were chemically analysed to obtain more information on rock compositions and to determine any trends of possible stratigraphic significance. The results obtained, together with those of analyses carried out for M. Owen, indicate three main features of interest. They are:

1. Similarities in composition between the Ainslie Volcanics, Gladefield Volcanics, and the volcanics in the Gooromon Ponds area which are a southern continuation of the Hawkins Volcanics east of Yass. The Ainslie Volcanics have until now been regarded as Lower Devonian whereas the other volcanics are mapped as Middle to Upper Silurian.
2. A greater similarity in composition of the Mount Painter Porphyry to the Middle to Upper Silurian Volcanics (and Ainslie Volcanics) than to the later Upper Silurian volcanics in the Woden area with which the porphyry is geographically associated; the significance of this is not clear.
3. A close similarity in composition, between the southern continuation into the Gooromon Ponds area of the Willow Bridge Tuff at Yass and an unnamed formation which extends from Mount Stromlo to northwest Tuggeranong.

1:50 000 Geological Map of Canberra

A revised version of the 1971 Canberra 1:50 000 special geological map, plus an extension into the Tuggeranong area, was compiled, taking into account additional mapping and interpretation since 1971 and correlations indicated by the chemical analyses of specimens of the volcanic formations.

1:10 000 engineering geology maps

Compilation of a series of engineering geology maps of urban Canberra, at 1:10 000 scale, continued.

Further revisions were made to the Coppins Crossing Sheet, and an overlay of the map plotted, together with reference tables and graphic logs of diamond-drill holes.

Further revisions were also made to the Canberra City Sheet which will be the second map in the series. Mapping in the Mount Ainslie area by vacation student B. Pillans provided additional geological information for inclusion on the map; also, data from recent building site investigations and mapping of excavations were plotted, including sites at Russell, opposite the Administration Building, and at the Canberra Technical College. The mapping around Mount Ainslie shows that the Ainslie Volcanics can be divided into a lower unit, consisting mainly of dacite with some agglomerate and an upper unit comprising dacite, andesite, and quartz andesite with lenses of white rhyolite. Thick deposits of colluvium flank the mountain in some places. Dacite overlying shale of the St John's Church Beds with apparent conformity was mapped in the Russell excavation.

SOILS INVESTIGATIONS, BY J. R. KELLETT

Soils mapping, classification, and determination of engineering properties formed an important part of several of the urban geology and drainage investigations.

Soil stratigraphy studies

Following field studies in Albury Wodonga in 1974, a soil stratigraphic column is being set up for Canberra soils and an index of their engineering properties is being collated. Four pediment clays were mapped on Mount Jerrabomberra. Representative samples were tested in the soil mechanics laboratory and their mineralogy was determined by X-ray diffraction. Twenty-nine backhoe pits were dug in Kowen forest. Mapping and testing of these soils are in progress.

MISCELLANEOUS, BY G. A. M. HENDERSON & E. G. WILSON

Mineral deposits north of A.C.T.

Notes on past and present mining activities in the area just north of the A.C.T. were prepared at the request of NCDC. The report included possible environmental effects of mining of any new mineral deposits which might be found as a result of current prospecting.

Refuse disposal in the A.C.T.

Advice was given to NCDC planners on geological aspects of sanitary landfill sites for refuse disposal around Canberra. A program of leachate monitoring was formulated. Seismic surveys of a landfill site at Pialligo, A.C.T., were carried out by the Engineering Geophysics Group to determine the degree of compaction of the refuse.

Rapid transit route

Preliminary studies were carried out along a possible rapid transit route in Canberra and advice was given to NCDC on ground conditions likely to be encountered.

ENGINEERING GEOLOGY OTHER THAN A.C.T. AND ENVIRONS, BY J. M. M. FURSTNER, G. JACOBSON & P. H. VANDENBROEK

A consultative and co-ordinating role was provided in aspects of the development of Geelong and Albury Wodonga.

Lower Waga Hydro-Electric Scheme, Papua New Guinea

A proposed hydro-electric scheme on the Waga River in the Southern Highlands of Papua New Guinea was inspected by G. Jacobson in May with a team of DHC engineers and an engineering consultant from Yugoslavia. The scheme is in an extensive area of karst limestone and the inspection was part of a study to decide whether development is feasible, what further investigations are needed, and preferred layouts. A report was prepared (Record 1975/137).

Ramu Hydro-Electric Scheme, Papua New Guinea

J. Furstner visited the site at the request of DHC in September to advise on the cause and location of water leakage from the pressure shaft, and its effect on the machine hall excavation. A drilling program to provide drainage in the rock adjacent to the machine hall was prepared comprising two angled diamond-drill holes, 30 m long, and 20 percussion holes 10 m long. Drilling is in progress.

Darwin East: environmental geology

P. H. Vandenbroek visited Darwin in March to inspect the groundwater drainage problems at Darwin East during the wet season. A report on the environmental geology of Darwin East was completed and will be published.

Newcastle Dry Dock

Geological advice was provided during the year for DHC engineers concerning the geology of the foundations. Four visits to the site were made by J. Furstner and the foundation geology was examined in detail from drill-hole information as part of an investigation into the possible effect of subsidence in abandoned coal workings near the site. Three additional angled diamond-drill holes were drilled, and a three-dimensional model of the geology of the foundations was prepared. A report is in preparation.

Australian National Animal Health Laboratory, Geelong

Advice on the geological conditions of the foundations of the buildings associated with this complex was provided for DHC. The complex is to be founded on fairly thin basalt at a depth of 10 m. An assessment of the existing drill-hole information was made, and a brief report prepared.

CONFERENCES AND COURSES

A number of staff members attended the ANZAAS Congress in Canberra in January. G. Jacobson and P. A. Lang attended the ANZ Geomechanics Conference in Brisbane in July; P. H. Vandenbroek attended the Fifth Underground Water School in Adelaide, and E. G. Wilson attended a conference in Adelaide on the 'Use of surface geophysical methods as applied to underground water' during August. P. D. Hohnen attended the Australian Water Well Drillers course on drilling at Dubbo in October. All officers of the Subsection attended a Rock Mechanics Course in Canberra conducted by Dr B. McMahon in June.

MAP EDITING AND COMPILATION

BY G. W. D'ADDARIO & W. D. PALFREYMAN

STAFF: G. W. D'Addario, W. D. Palfreyman, D. E. Gardner, J. M. M. Bultitude

GENERAL

Map Committee meetings to review progress, priorities, and program were held on 4 February and 21 August. Visits were made to all State Geological Surveys in connexion with the compilation of the 1:2 500 000-scale geological map of Australia. D. Palfreyman prepared a paper for inclusion in the Taylor Memorial Volume on Volcanology.

Advice was given to various authors on aspects of map and reference compilation.

A new draft of the Standard Geological Symbols booklet was prepared for the consideration of State and Territory Geological Surveys and BMR staff.

EDITING

Eight special maps (i.e. other than standard-scale series maps) and thirty 1:250 000-scale colour maps were edited. The editing of five special and four 1:250 000-scale maps is in progress.

COMPILATION

Geology of Papua New Guinea 1:2.500 000-scale map (D. B. Dow, G. W. D'Addario)

Compilation and checking of the map was completed; printing is in progress. The accompanying notes have been written by D. Dow and are with the text editors.

Geology of Australia, 1:2.500 000-scale map (W. D. Palfreyman, G. W. D'Addario, J. M. M. Bultitude)

This will be a five-sheet map, including a sheet of four 1:10 000 000-scale maps.

Compilation and checking of the four sheets which form the main map and reference were completed. The geological plates for the four sheets have been scribed. The accompanying notes are being written.

The 1:2.500 000-scale map will show sedimentary and metamorphic sequences by age colour and igneous rocks by rock-type colour (with tinting for different ages). Cainozoic cover will be shown by overprinted stipples. The four accompanying 1:10 000 000-scale maps of Australia portray the main rock types, Cainozoic thickness and depth of weathering, surface drainage and features of the continental margin, and the major tectonic elements including sedimentary basins. All four maps have been compiled.

Geology of Australia, 1:10 000 000-scale map (G. W. D'Addario, J. M. M. Bultitude)

Compilation of this map, which is designed for inclusion in both the BMR Atlas of Maps and the third series of the Division of National Mapping's Atlas of Australian Resources, is in progress.

The map will form the first sheet of an atlas that the Bureau has decided to produce. Most maps will be at 1:10 000 000 scale; all facets of the geology and geophysics of Australia and the surrounding oceans will be portrayed as available data and resources permit. Several map sheets will be prepared during 1976. The Atlas will be in loose-leaf form and will have hard covers.

Geology of the Northern Territory, 1:2.500 000-scale map (G. W. D'Addario)

The fair drawing was checked and the map is with the printer.

Cainozoic of the Northern Territory, 1:2.500 000-scale map (G. W. D'Addario)

The final compilation was checked and the map is being fair drawn.

INDEXES AND MINERAL REPORTS
BY K. MODRAK & N. D. KNIGHT

STAFF: K. Modrak, N. D. Knight, L. E. Walraven (temporarily transferred to Operations Branch, 19 May), M. Pollington (from 4 August), L. Kay and M. Tacon (part time)

STRATIGRAPHIC INDEX

Literature received through the BMR Library was indexed under the headings: stratigraphic name, author, 1:250 000 Sheet area, Basin name, and broad subject heading. Copies of the index cards, where requested, were sent to the Library, State Geological Surveys, and the Basin Study Group.

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, noting additions to the Central Register, were compiled and sent to State Geological Surveys, Universities, and interested companies. Entries in the lists for the 12-month period, November 1974 to October 1975, totalled 880.

Enquiries and visits from authors, State Survey officers and others regarding stratigraphic names, definitions, and literature references were received and answered. Over 100 written enquiries, involving several hundred names, were replied to by letter.

A report, for the period May 1974 to February 1975, to the Council of the Geological Society of Australia was compiled and submitted.

On 20 January the Stratigraphic Nomenclature Committee met in Canberra. The group assisted E. Carter, the Convener, in preparing the agenda and minutes for the meeting. An open meeting on the Australian Stratigraphic Code was held on 22 January and again the group assisted the Convener.

The manuscript of Volume 5h—Australia, General, of the International Stratigraphic Lexicon is in the 2nd proof stage. Professor J. Avias of the Lexique Stratigraphique International visited the section and discussed the Lexicon with the convener.

A draft of the AMF Thesaurus was used in the group for a trial period during December and January. K. Modrak attended the AMF seminar on 'Geoscience Information', held in Adelaide 10-12 March 1975, at which one of the items of discussion was the Thesaurus. The working party, formed at the seminar, met in BMR on 23 May; K. Modrak attended as an observer.

The checking of papers to be published by the Australasian Institute of Mining and Metallurgy in the four-volume 'Economic Geology of Australia and Papua New Guinea' was completed.

In the mid part of the year the ADP section undertook, with the assistance of K. Modrak, a feasibility study to convert the Stratigraphic Index to machine-readable form. At present the basic specifications for such a system are being compiled.

TECHNICAL FILES

Indexing of unpublished data and newspaper clippings continued; these were filed under 1:250 000 Sheet areas. Use was made of the files to answer technical enquiries from BMR officers and authorized visitors. Enquiries were received at a rate of 200 to 300 per year.

MINERAL INDEX AND MINERAL RESOURCES 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. The Mineral Resources Report on tin deposits was edited and is now in press. A similar report on molybdenum was submitted to the editors, and a report on antimony was compiled. Further work was done on a report on tungsten.

N. D. Knight attended a conference, in November 1974, on gold deposits in Victoria.

MUSEUM AND TRANSIT ROOM

BY D. H. MCCOLL

STAFF: D. H. McColl, J. D. Reid, R. Black (temporary Feb-May), G. Sparksman, C. Madden, G. Price, G. Fisher (Trainee Technical Officers—part time). G. D. Nolan, Transit Room.

MUSEUM

Collections

Two notable additions have significantly contributed to the quality and value of the reference mineral holdings this year. In April the collection of Mr R. Noble of Adelaide was purchased for $11 000. It consists of 400 museum-quality specimens derived mainly from Western Australia and South Australia. Telluride minerals from the Kalgoorlie mines, and historic copper ores from the Burra and Moonta mining districts, are well represented.

In October, 364 specimens comprising the mineral collection of Mr C. M. Chidley of Sydney were received by donation to the national collection. Almost all the specimens are crystallized and many also are of gem quality. They are predominantly derived from overseas localities, and some are the finest examples of their type in Australia. The donation was formally received by the Acting Deputy Secretary, Mr J. M. Reddy, on 15 October, and Mr Chidley was thanked for his very fine and generous gesture: the collection is worth many thousands of dollars.

An assortment of other specimens has been obtained through collection, exchanges, and purchase. Field collecting was done in the Broken Hill, Olary, and Flinders Ranges areas. Notable specimens collected included 128 australites from the Lake Torrens strewnfield, and meteorites from near Nilpean in South Australia and Thackaringa in New South Wales.

Considerable improvements have been made during the past year in accessibility of information on the reference collections, portions of which are now computer-catalogued. Detailed individual specimen inventories and catalogues have also been assembled covering some of the oldest collections for the first time. In summary, the reference mineral collections consist of the following: (see page 127).

Displays

A special display of Australian gemstones was organized with assistance from various local enthusiasts and companies, to coincide with the ANZAAS conference in January. This was attended by some hundreds of visitors.

In March three showcases and a manned identification service were provided in the foyer of the Lakeside Hotel for the *Australia 75* exhibition. About 3000 people visited the display during the 9-day period.

In April the Museum was represented at the 1975 Gemboree, held for the first time at Broken Hill. Two showcases of spectacular

Year obtained		Number of specimens	Valuation ($, approximate)
1961	C. B. Askew Mineral Collection	1009	12 000
1962	R. W. Doo Mineral Collection	2000 approx	18 000
1964	A. R. Campbell Mineral Collection	900 approx	22 000
1974	A. E. Gardner Mineral Collection	1280	17 000
1975	R. J. Noble Mineral Collection	400	12 000
1975	C. M. Chidley Mineral Collection	364	20 700
1950-75	BMR Mineral Collections	4000 approx	18 000
1950-75	Meteorite Collection	25 principal specimens	8 000
1950-75	Gold Specimens	6 principal specimens	2 500

mineral pieces from the Campbell mineral collection were displayed. These originally came from Broken Hill, and Campbell was a well known identity in that city, so it was particularly appropriate.

In August a single showcase of gold and telluride minerals was provided for the first National Exhibition of Minerals which was conducted at Glen Waverley in Victoria. This was the largest mineralogical function of its kind ever held in Australia and was supported by all major museums and collectors; about 15 000 people attended.

An extended loan of a very fine display of cut and polished agates from Agate Creek in North Queensland has been arranged with local collector Mr H. Bruce of Hackett, A.C.T. This has been shown throughout the year in the foyer and corridors of the BMR building.

New displays featuring tektites, zeolites, gold, and new collections have also been provided intermittently within BMR during the year. The Sydney regional office of the Department of Minerals & Energy also features displays provided from Canberra on a six-monthly basis.

Educational and other external services

Organized visits by classes of school children were catered for as in recent years; several hundred children in groups of 20 to 37, were shown over the Museum. Elementary sets of rocks and minerals suitable for teaching were provided on formal request. Other institutions assisted in various ways include the Australian National University, Canberra Technical College, Canberra College of Advanced Education, the Australia-Japan Society, the Canberra Gem Society, and various Embassies and State Universities. A special service concerned the provision of a gift display of Australian ores and minerals by request of the Australian Embassy in the Netherlands.

Various services have been rendered to other government departments, particularly the National Museums Secretariat of the Department of the Special Minister of State which required mineralogical and gemmological assessments of three very valuable Australian specimens which had been offered for purchase. Visits to the potential vendors in Rockhampton, Emerald, and Sydney were involved. The specimens were not purchased because of current economic constraints.

Visitors

Within the limitations of the present staff and facilities the Museum continues to provide the functions of an earth science museum for tourists and the general public of the Canberra region. As well as students several hundred people of all ages and interests have brought specimens to be identified, to see displays, or make enquiries about the local geology. Amateur prospecting and gemmology continue to attract most interest from the average visitor.

TRANSIT ROOM

Samples collected by survey parties requiring petrological, petrographic, chemical or radio-isotope investigations are forwarded to contractors or relevant BMR laboratories by the officer-in-charge (G. Nolan). Effort continues toward the unification of past and present sample and research results with all relevant project data into a single storage and retrieval system which, ideally, will be computerized.

The total number of samples processed was 10 041, which comprise the following classifications:

Thin section preparations	4173
Polished section preparations ..	42
Polished thin section preparations ..	627
Age determinations (various)	199
Chemical analyses (various)	4498
Palaeontological sectioning and sundry investigations	502

GEOLOGICAL DRAWING OFFICE

BY P. A. BOEKENSTEIN & M. E. NANCARROW

GENERAL

H. F. Boltz, Chief Draftsman, retired on 4 July 1975 after 26 years' distinguished service with BMR. P. A. Boekenstein, former Assistant Chief Draftsman, was promoted to Chief Draftsman.

The photographer positions in the office were reclassified during the year and the occupants were promoted to the reclassified positions.

Throughout the year, H. F. Boltz and P. A. Boekenstein attended monthly meetings of the Australian Government Publishing Service (AGPS)-BMR Printing and Publications Co-ordinating Committee, quarterly meetings of the Department of Minerals & Energy Trainee Draftsmen Committee, and the BMR-Division of National Mapping (DNM) Liaison Committee. From July, M. E. Nancarrow attended monthly meetings of the DNM-BMR-NCDC Drafting Aids Committee.

Three cartographic staff worked in the field as members of geological field parties: D. M. Pillinger, Duchess Party; J. M. Mifsud, Georgetown Party; D. G. Walton, Georgina Basin Party. P. Fuchs, Darwin Office, visited BMR for two weeks to discuss the 1975-76 drafting program for Darwin, and to familiarize himself with developments in 1:100 000-scale drafting techniques.

J. Rau, Drafting Assistant, Geological Survey of Papua New Guinea, joined the Geological Drawing Office on 1 September 1975 for four months' training in regional geological map compilation and general drafting.

J. M. Fetherston, Senior Draftsman, whilst in London, spent five days with the Experimental Cartography Unit, Royal College of Art, in order to evaluate aspects of automated cartography for a BMR project team set up to investigate the possible applications of automation to the production of Preliminary Edition geological maps.

Investigations continued in the Drawing Office into the application of automated cartography to geological map production. On some Preliminary Edition maps scribing was used successfully for the final compilation stages.

In July 1975, J. M. Fetherston was seconded to a Review Team established by departmental management and staff associations to examine existing working and organizational arrangements of professional and drafting/technical-grade positions in BMR.

PRODUCTION
(November 1974 to October 1975 inclusive)

Supervising Draftsmen: K. Matveev, H. Hennig, R. Molloy, E. Feeken

Maps for publication

	1:100 000	1:250 000	Other scales
(a) Preliminary Edition			
Compilation by BMR in progress	9	6	—
Compilation by BMR completed (ready for printing)	3	1	—
Preliminary Edition printed	6	19	2
(b) 1st or 2nd Edition			
Fair drawing in progress			
BMR	—	—	2
Contract*	2	19	7
Fair drawing completed			
BMR	—	—	2
Contract*	—	15	2
Printing** in progress			
BMR	—	11	4
GSWA	—	2	—
Printing** completed			
BMR	—	15	1
GSWA	—	3	—
Reprinting	—	3	1

Notes: *Contract drafting stages over the period: specifications prepared—32 maps; contractor recommended—31 maps; first proof checked—14 maps; second proof checked—14 maps.

**Printing stages over the period: specifications prepared—32 maps; colour designs and colour guides prepared—37 maps; performance supervised as required, screen masters and dyeproofs checked—17 maps; machine proofs checked—17 maps; printed maps checked—19 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)

Compilation and fair drawing of 1:2.5 million Geological Map of Papua New Guinea was completed and the printer's dyeproof was checked.

Printing of the 1:2.500 000 Geological Map of the Northern Territory commenced in October, and fair drawing of the companion map, 'Cainozoic Stratigraphy of the Northern Territory' was in progress.

Compilation of the 1:2.500 000 Geological Map of Australia was completed, fair drawing of the northwestern sheet was completed, colour guides of all four sheets were completed and checked, and printing specifications were submitted to AGPS. Several special pattern screens were prepared for use on this and other multi-colour maps.

Field Compilations (1:250 000 or 1:100 000 Sheet areas): 16 completed

Text figures, diagrams, plates

	Drawings completed	Drawings in progress
Records and miscellaneous	727	124
Reports	142	64
Explanatory Notes	31	26
Bulletins	294	152
Outside publications	30	10

Pictorial Index of Activities

The Pictorial Index of Activities to 31/12/74 was compiled and published. This is expected to be the last issue of the Pictorial Index; it will be replaced by two or more broadsheet brochures issued twice a year.

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

83A. Jones, H. A. & Burgis, W. A.—A revision of the geological map of the Timor Sea.
121. [1]Opik, A. A.—Templetonian and Ordian xystridurid trilobites of Australia.
151. Burger, D.—Cenomanian spores and pollen grains from Bathurst Island, Northern Territory, Australia; [1]Norvick, M. & Burger, D.—Stratigraphic palynology of the Cenomanian of Bathurst Island, Northern Territory, Australia.
153. Shergold, J. H.—Late Cambrian and Early Ordovician trilobites from the Burke River Structural Belt, western Queensland, Australia.
154. Jensen, A. R.—Permo-Triassic stratigraphy and sedimentation in the Bowen Basin, Queensland.
155. (PNG Bulletin 9). Bain, J. H. C., Mackenzie, D. E. & Ryburn, R. J.—Geology of the Kubor Anticline, Central Highlands of Papua New Guinea.
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. [1]Opik, A. A.—Cymbric Vale fauna, and Early Cambrian biostratigraphy.
160. Burger, D.—Some Early Cretaceous plant microfossils from Queensland, Australia; Kemp, E. M.—Palynological observations in the Officer Basin, Western Australia.
162. Page, R. W.—Geochronology of igneous and metamorphic rocks in the New Guinea Highlands.
166. Exon, N. F.—Geology of the Surat Basin in Queensland.
167A. Senior, B. R., Mond, A., & Harrison, P. L.—Notes on the geology of the northern part of the Eromanga Basin.
167B. Senior, B. R.—Notes on the geology of the central part of the Eromanga Basin.
171. [4]Pojeta, J., Jnr, Gilbert-Tomlinson, Joyce & Shergold, J. H.—Cambrian and Ordovician rostroconch molluscs from northern Australia.
174. [4]Pojeta, J., Jnr & Gilbert-Tomlinson, Joyce—Australian Ordovician pelecypod molluscs.

With Editors

163. Marshall, J. F.—Marine geology of the Capricorn Channel area.
165. [1]Smith, I. E. Davies, H. L., & Belford, D. J.—Geology of the southeast Papuan mainland.
167C. Mond, A. & Harrison, P. L.—Notes on the geology of the northwestern part of the Eromanga Basin, Northern Territory and Queensland.
168. Sweet, I. P.—Precambrian geology of the Victoria River region.
169. Sheraton, J. W. & [1]Labonne, B.—Petrology and geochemistry of acid igneous rocks of northeast Queensland.
170. Cook, P. J. & Mayo, W.—Sedimentology and Holocene history of a tropical estuary (Broad Sound, Queensland).
172. Opik, A. A.—Middle Cambrian Agnostaceae.
176. Hohnen, P. D.—Geology of New Ireland, Papua New Guinea.
177. Hughes, R. J.—Geology and mineral occurrences of Bathurst Island, Melville Island, and Cobourg Peninsula, N.T.
182. Derrick, G. M., [2]Wilson, I. H., Hill, R. M., Glikson, A. Y., & Mitchell, J.—Geology of the Mary Kathleen 1:100 000 Sheet area, northwest Queensland.
— Crespin Commemorative Volume—Belford, D. J.—The genus *Triplasia* (Foraminiferida) from the Miocene of Papua New Guinea; Dickins, J. M.—Relationship of *Mourlonia* and *Ptychomphalina*, Upper Palaeozoic Gasteropoda; Druce, E. C.—Correlation of the Cambrian-Ordovician boundary in Australia; Kemp, E. M.—Microfossils of fungal origin from Tertiary sediments on the Ninetyeast Ridge, Indian Ocean.
— Davies, P. J.—Marine geology of the continental shelf off southeastern Australia.

REPORTS

Published or in press

152. [1]Gellatly, D. C., Derrick, G. M., & Plumb, K. A.—Geology of the Lansdowne 1:250 000 Sheet area, W.A.
162. [1]Bennett, R., Page, R. W., & Bladon, G. M.—Catalogue of isotopic age determinations carried out on Australian rocks, 1966-70.
167. Sweet, I. P., [1]Mendum, J. R., Bultitude, R. J., & [1]Morgan, C. M.—The geology of the southern Victoria River Region, Northern Territory.
171. [1]Burgis, W. A.—Environmental significance of folds in the Rangal Coal Measures at Blackwater, Queensland.
172. [1]Burgis, W. A.—Cainozoic history of the Torilla Peninsula, Broad Sound, Queensland.
174. Blake, D. H., Hodgson, I. M., & Smith, P. A.—Geology of the Birrindudu and Tanami 1:250 000 Sheet areas, N.T.
188. Exon, N. F. & Morrissey, J.—Wireline logging of water bores in the Surat Basin, 1960 to 1974.
189. Geological Branch Summary of Activities, 1974.
195. [5]de Deckker, P. & Jones, P. J.—Check list of Ostracoda recorded from Australia and Papua New Guinea (1845-1973).

With Editors

186. Stewart, A. J.—Petrographic and geochemical study of the Ringwood evaporite deposit, N.T.
— Black, L. P.—Isotopic ages of rocks from the Georgetown-Mount Garnet-Herberton area, north Queensland.
— Draper, J. J. & Jensen, A. R.—The sediments and geochemistry of Lake Frome, South Australia.
— Druce, E. C. & Radke, B. M.—Geochemistry of the Fairfield Group, Canning Basin, Western Australia.

MINERAL RESOURCES REPORTS

6. [1]Ingram, J. A.—Uranium deposits *(published)*.
7. [1]Ingram, J. A.—Tin deposits *(in press)*.

BMR JOURNAL OF AUSTRALIAN GEOLOGY AND GEOPHYSICS

Volume 1, Number 1 *(in press)*

Papers

Page, R. W., Blake, D. H., & Mahon, M. W.—Geochronology and related aspects of acid volcanics, associated granites, and other Proterozoic rocks in The Granites-Tanami region, northwestern Australia.

McEwin, A., Underwood, R., & Denham, D.—Earthquake risk in Australia.

Spies, B. R.—The Transient Electromagnetic Method in Australia.

Exon, N. F. & Senior, B. R.—The Cretaceous of the Eromanga and Surat Basins.

Plumb, K. A., Shergold, J. H., & [4]Stefanski, M. Z.—Significance of Middle Cambrian trilobites from Elcho Island, Northern Territory.

Anfiloff, W.—Automated density profiling over elongate topographic features.

Radke, B. M.—Hierarchical classification and vector ordination in the distinction of limestones in the Fairfield Group, Canning Basin, Western Australia.

Notes

Yeates, A. N., [2]Crowe, R. W. A., & Towner, R. R.—The Veevers Crater: a possible meteoritic feature.

Plane, M.—The occurrence of *Thylacinus* in Tertiary rocks from Papua New Guinea.

Discussion

Page, R. W.—Reinterpretation of isotopic ages from the Halls Creek Mobile Zone, northwestern Australia.

OUTSIDE PUBLICATIONS

(published or in press)

[4]Armstrong, R. L. & Stewart, A. J.—Rubidium-strontium dates and extraneous argon in the Arltunga Nappe Complex, Northern Territory. *J. geol. Soc. Aust.* 22, 103-15.

[4]Awramik, S. M., [4]Logan, B. W., [4]MacGregor, A. R., [2]Playford, P. E., [4]Rezak, R., [4]von der Borch, C. C., & Walter, M. R.—Conservation of Hamelin Pool, Western Australia, *Dept. Envir. Protection, W.A.*, March 1975.

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[3]Bubela, B., Ferguson, J., & Davies, P. J.—Biological and abiological processes in a simulated sedimentary system. *J. geol. Soc. Aust.* 22, 135-44.

Chaproniere, G. C. H.—Palaeoecology of Oligo-Miocene larger Foraminiferida from Australia. *Alcheringa*, 1, 31-52.

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[3]Donnelly, T. H., Ferguson, J., & [4]Eccleston, A. J.—A high-speed method of continuous background correction in atomic absorption spectrometry. III, Direct determination of trace metals in sea water using the Varian Techtron Carbon Rod Atomiser Model 63, *Appl. Spectrosc.* 29(2), 158-63.

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[4]FRAKES, L. A., KEMP, E. M., & [4]CROWELL, J. C.—Late Palaeozoic glaciation. VI—Asia. *Bull. geol. Soc. Amer.*, 86, 454-64.

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JOHNSON, R. W.—Plate model for late Cainozoic volcanism at the southern margin of the Bismarck Sea, Papua New Guinea. *Bull. Aust. Soc. explor. Geophys.* 6, 71-72.

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