COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1971/64

GEOLOGY OF THE BOWEN BASIN, QUEENSLAND

by

J. M. Dickins and E. J. Malone

Record 1971/64

GEOLOGY OF THE BOWEN BASIN, QUEENSLAND

by

J.M. Dickins and E.J. Malone

CONTENTS

	Page
SUMMARY	1
INTRODUCTION	6
Access	8
Population and Industry	9
Climate, Vegetation, and Drainage	9
Physiography	10
Previous Investigations	10
LOWER PALAEOZOIC	12
Anakie Metamorphics	12
Lower Palaeozoic Metamorphics	14
Mount Windsor Volcanics	14
SILURIAN TO MIDDLE DEVONIAN	15
Silurian-Devonian	15
Ukalunda Beds	16
Dunstable Volcanics	19
Douglas Creek Limestone and Equivalents(?)	20
Unnamed Palaeozoic Metamorphics	21
DEVONIAN TO CARBONIFEROUS	21
Drummond Basin Sequence	22
Mount Rankin Beds	23
Theresa Creek Volcanics	25
Connors Volcanics	26
Campwyn Beds	27
Yarrol Basin Sequence	28
UPPER CARBONIFEROUS TO PERMIAN	30
Bulgonunna Volcanics	31
Joe Joe Formation	32
Torsdale Beds	33
LOWER PERMIAN AND OLDER	33
Camboon Andesite	33
Gogango Range area	34
Monto Sheet area	37
Mundubbera Sheet area	37
Rannes Beds	38
Conclusions	41
PERMIAN-TRIASSIC STRATIGRAPHY OF THE BOWEN BASIN	42

Page

EARLY LOWER PERMIAN 43

Reids Dome Beds 43
Carmila Beds and Lizzie Creek Volcanics 45
Relationships and Tectonics 47

BACK CREEK GROUP 49

Tiverton Subgroup 50
Tectonics and Sedimentation 53

Gebbie Subgroup 53
Relationships to Underlying Rocks 54
Fluvial Environment in the Western Bowen Basin .. 55
Deltaic Environment of the Denison Trough 56
Paralic Environment of the Comet Ridge and
Collinsville Shelf 57
Marine Environment of the Eastern Bowen Basin .. 58
Coal Measure Environments 60
Collinsville Coal Measures 61
Calen Coal Measures 62
Blair Athol Coal Measures 62
Tectonics 63

Blenheim Subgroup 63

Lutite Province 64
Lutite/Arenite Province 66
Flysch(?) Province 67
Lutite/Quartzose Arenite Province 69
Coquinite Horizons 70
Paralic Province 71
Comet Ridge-Folded Zone 73
Depositional Tectonics 73

PERMIAN ROCK UNITS OF THE EUNGELLA-CRACOW
MOBILE BELT 75

Unnamed Lower Permian 75
Rookwood Volcanics 76

BLACKWATER GROUP 77

Depositional Tectonics 80

PERMIAN PALAEONTOLOGY AND CORRELATION BASED
ON MARINE INVERTEBRATES 81

Page

MIMOSA GROUP 86

Rewan Formation 86
Clematis Sandstone 88
Moolayember Formation 90
Age of the Mimosa Group 92
Relationships of the Mimosa Group 93

GREAT ARTESIAN BASIN SEQUENCE 94

Structure 96
Depositional History 98

STYX COAL MEASURES 100

TERTIARY 101

CAINOZOIC 102

IGNEOUS ROCKS 103

Intrusive History 103
Retreat Granite 104
Devonian and Carboniferous Intrusives 104
Carboniferous Intrusives 105
Auburn and Urannah Complexes 105
Serpentinite 107
Upper Permian Intrusives 107
Cretaceous Intrusives 108
Cretaceous or Tertiary Intrusives and Extrusives .. 109
Tertiary Intrusives and Extrusives 109
Basalt 109
Acid to Intermediate Volcanics 110

STRUCTURE 110

Clermont Stable Block 111
Central and Western Parts of the Bowen Basin 113
Western Bowen Basin 113
Denison Trough 113
Comet Ridge 115
Capella Block 115
Collinsville Shelf 116
Nebo Synclinorium 116
Folded Zone 117
Mimosa Syncline 118
Duaringa Basin 118

Page

Eungella-Cracow Mobile Belt 119
Connors Arch.. 119
Calen Area.. 119
Campwyn Block 120
Carmila Syncline 121
Strathmuir Synclinorium 121
Styx Basin.. 121
Leura Area 122
Gogango Overfolded Zone 122
Craigilee Area 123
Marlborough Block 124
Long Island Area 124
Auburn Arch 125
Prospect Creek Area 125
Biloela Basin 125

GEOLOGICAL HISTORY 125

Clermont Stable Block (pre-Permian rock units) 125
Eungella-Cracow Mobile Belt (pre-Permian rock units) .. 128
Permian-Triassic 131
Jurassic-Cretaceous 135
Cainozoic.. 136

ECONOMIC GEOLOGY 137

Groundwater 137
Coal.. 138
Oil and Gas 138
Gold 140
Copper 140
Other Metals and Minerals 141

BIBLIOGRAPHY 142

TABLES

1. Devonian-Carboniferous rock units of the Clermont Block 171

2. Devonian-Carboniferous rock units of the Eungella-Cracow Mobile Belt 173

3. Upper Carboniferous to Permian rock units 175

4. Early Lower Permian rock units 176

5. Sequences penetrated in petroleum exploration wells .. 177

6. Rock units of the Tiverton Subgroup 180

Page

7. Rock units of the Gebbie Subgroup (southern part of Bowen Basin) 182
8. Rock units of the Gebbie Subgroup (northern part of Bowen Basin) 183
9. Possible equivalents of the Gebbie Subgroup 184
10. Rock units of the Blenheim Subgroup 185
11. Permian rock units of the Eungella-Cracow Mobile Belt 188
12. Rock units of the Blackwater Group.. 189
13. Distribution chart of Permian species 191
14. Rock units of the Mimosa Group 195
15. Rock units of the Great Artesian Basin sequence 197
16. Igneous rocks.. 201

APPENDIX. Isotopic dating of igneous rocks of eastern Queensland, by A.W. Webb 206

PLATES

1. Solid geology of the Bowen Basin) At back
2. Block diagram of the Bowen Basin) of
3. Tectonic units and structural subdivisions (with aero-magnetic and gravity data)) Record

FIGURES

1. Age groupings of main rock units
2. Locality map
3. Area covered by BMR maps and reports
4. Distribution of the Ukalunda Beds
5. Distribution of the Dunstable Volcanics
6. Geology of the Long Island area
7. Correlation of Permian formations
8. Distribution and outcrops of the Camboon Andesite, Reids Dome Beds, Carmila Beds, and Lizzie Creek Volcanics

9. Distribution of the Tiverton Subgroup

10. Sections of the Tiverton Subgroup

11. Symbols and abbreviations used in columnar sections

12. Distribution and outcrops of the Gebbie Subgroup and its equivalents

13. Sections of the Gebbie Subgroup

14. Distribution and outcrops of the Blenheim Subgroup

15. Sections of the Blenheim Subgroup

16. Distribution and outcrops of the Blackwater Group

17. Sections of the Blackwater Group

18. Distribution and outcrops of the Rewan Formation

19. Distribution and outcrops of the Clematis Sandstone

20. Distribution and outcrops of the Moolayember Formation

SUMMARY

The Bowen Basin, comprising essentially Permian and Triassic rocks, is situated in central and southern Queensland and, beneath the surface of the Great Artesian Basin, is possibly continuous with the Sydney Basin. This Bulletin is concerned mostly with the northern exposed part of the basin, its eastern, northern, and western margins, and the eastern extension of the Great Artesian Basin, the Surat Basin, which covers the southern part of the Bowen Basin.

Lower Palaeozoic rocks are found along the western and possibly eastern margins. The Anakie Metamorphics on the west comprise schist and gneiss with widespread quartz veins and reefs. An isotopic age of 450 m.y. has been determined. Granite associated with the metamorphics in the Telemon Anticline has been found to have a similar age. Metamorphics near Marlborough have been assigned a Lower Palaeozoic age because of their degree of alteration. The Mount Windsor Volcanics in the northwestern corner of the map area are also regarded as Lower Palaeozoic.

In the east, Lower Silurian to Middle Devonian rocks are found south of Marlborough, and in the west they consist of the Ukalunda Beds, Dunstable Volcanics, and Douglas Creek Limestone. Basic to intermediate volcanics, chert, and limestone are prominent. Corals are important in the rather meagre marine faunas and some reefs may have been formed around volcanic islands or submarine mountains. The beds are separated by an angular discordance from the Lower Palaeozoic rocks.

In Devonian to Carboniferous times, sediments were deposited in three large basins: the Drummond Basin, a basin in which the Mount Rankin Beds (with the Mount Wyatt Beds at the base) were laid down, and the Yarrol Basin. Outside these basins the Theresa Creek Volcanics were deposited on the Anakie Inlier. The Campwyn Beds were formed in what may be the northern extension of the Yarrol Basin, and the Connors Volcanics accumulated west of the Yarrol Basin. The Camboon Andesite as mapped appears to contain equivalents of the Connors Volcanics. Volcanics and sediments are found in all areas, but marine conditions have been identified only in the Mount Wyatt Beds and in the Yarrol Basin and its possible extension occupied by the Campwyn Beds.

In Upper Carboniferous to Permian times the Bulgonunna Volcanics, Joe Joe Formation, and Torsdale Beds were deposited in widely separated areas around the margin of the Bowen Basin. The Bulgonunna Volcanics are terrestrial and predominantly acid. They are intruded by granite with an

isotopic age of 285 m.y. The granite is overlain by the Lizzie Creek Volcanics (previously called the Lower Bowen Volcanics) which contain a Glossopteris flora and near the top a marine fauna (Fauna I of Dickins, in Malone, Corbett, & Jensen, 1964; Malone, Jensen, Gregory, & Forbes, 1966) which is not older than late Sakmarian and may be early Artinskian. The Joe Joe Formation is partly glacial in origin and contains a Rhacopteris flora.

The Camboon Andesite and the Rannes Beds appear to contain rock units of different ages. The Camboon Andesite includes Lower Permian rocks as well as an older suite of pre-Upper Carboniferous age. The Rannes Beds are affected by low-grade regional metamorphism in a structurally complex area; they contain strata of Permian age as well as, apparently, older rocks. The Boomer Formation of the Back Creek Group is separated from part of the Rannes Beds by an angular unconformity.

The history of the Permian-Triassic sequence is complex. In the Permian the basinwide threefold subdivision corresponds to the Lower, Middle, and Upper Series of Jack (1879a), which were later referred to as Lower, Middle, and Upper Bowen Formations. Early in the Permian four units were formed in largely separated areas; the Reids Dome Beds in the Denison Trough, the Camboon Andesite in the Auburn Arch area, and the Lizzie Creek Volcanics (previously Lower Bowen Volcanics) and the Carmila Beds in the northern part of the Bowen Basin. Accumulation was apparently non-marine until the sea entered the area during late Lizzie Creek Volcanics time. The Reids Dome Beds contain numerous beds of coal, and consist of a thick sequence of entirely or predominantly non-volcanic rocks. The Camboon Andesite and Lizzie Creek Volcanics are largely intermediate volcanics with some sediments, whereas the volcanics of the Carmila Beds, which were laid down farther east, are mainly acid.

The middle part of the Permian sequence, the Back Creek Group (previously Middle Bowen Beds), is more widespread and has been subdivided into three subgroups which can be recognized throughout the basin. The predominantly marine Tiverton Subgroup is thickest in the Denison Trough and on the Connors Arch and Nebo Synclinorium, and thinnest over the Comet Ridge and to the southeast. In the Gebbie Subgroup quartz sandstone is widespread. In the north the Gebbie Subgroup overlaps the Tiverton Subgroup and rests directly on the Lizzie Creek Volcanics. In the west, the Gebbie Subgroup is represented by the relatively thin Colinlea Sandstone, which rests directly on the Reids Dome Beds, Joe Joe Formation, or older rocks. The Gebbie Subgroup was apparently not deposited in the Cracow area in the southwest. The environment of deposition ranged from non-marine, including coal measures in places, to offshore marine. The isolated Blair Athol Coal Measures, and probably also the Calen Coal Measures, are of this age. The youngest part of the Back Creek Group, the Blenheim Subgroup, began with a major marine transgression in late Lower Permian or early Upper Permian. In the north, west, southwest, and southeast, the Gebbie Subgroup overlaps the older parts of the Back Creek Group. It is largely marine, but lateral variation is considerable and coal measures were formed in the west and north. In the east, where the basin was less stable, the Blenheim Subgroup is represented by the flysch-like Boomer Formation with spilitic pillow lavas (Rookwood Volcanics) at the base. Each of the sequences is characterized by a distinctive marine fauna - Faunas II, III, and IV of Dickins (in Malone, et al., 1964, 1966).

In the Upper Permian, the Bowen Basin was cut off from the sea by uplift along the eastern margin, and the Blackwater Group (previously Upper Bowen Coal Measures) was deposited in the trough. The granites on the eastern margin, which have an isotopic age of about 240 m.y., were probably emplaced during the uplift and are of the same age as the volcanics within the Blackwater Group. The sedimentary cycle was complex and numerous formations have been recognized. Coal is known at several levels. The coal measures at the top of the group, which have been given different names in different areas, are almost continuous throughout the basin. These measures and the Upper Coal Measures in the Hunter Valley of New South Wales are among the most important sources of black coal in the southern hemisphere. The Blackwater Group contains a rich Glossopteris flora from which Taeniopteris has been recorded. The spore assemblage is distinct from that of the overlying Rewan Formation.

The Triassic sequence (Mimosa Group) comprises three formations of basin-wide extent: the Rewan Formation, Clematis Sandstone, and Moolayember Formation, all of which were laid down in a non-marine environment. The Rewan Formation consists of lithic sandstone and green and red-brown mudstone, which indicates a change in climate. On the margins of the basin the boundary with the Blackwater Group is disconformable, but in the central area it is possibly transitional. The Clematis Sandstone is predominantly quartzose; minor red-brown mudstone has been recorded. The succeeding Moolayember Formation consists mainly of mudstone and lithic sandstone laid down under less stable conditions than those which existed during the deposition of the Clematis Sandstone. The lower part of the Rewan Formation may be Permian in age, but the remainder of the Mimosa Group is Triassic. Uplift, folding, and erosion took place in the

Upper Triassic, and in the Lower Jurassic the Great Artesian Basin and its eastern lobe, the Surat Basin, were developed as separate structures. The Jurassic formations are mainly terrestrial, except for possible ephemeral marine incursions. The terrestrial environment persisted into the Lower Cretaceous until the sea entered from the north and west in Aptian-Albian time. This latest marine transgression was peripheral to the area described in this Bulletin. The Styx Coal Measures were laid down unconformably on Permian rocks in the Strathmuir Synclinorium in the Lower Cretaceous.

Terrestrial Tertiary deposits are widespread. The thickest sequence is in the Duaringa Basin where a thickness of 1050 m has been suggested. Basalt and associated intermediate and acid rocks, with isotopic ages ranging from 20 to 30 m.y., are found over large areas. In Tertiary and Quaternary times, the whole area was subjected to a long period of deep weathering during which lateritic profiles were strongly developed.

The age of the granitic intrusions along the western and eastern margins of the basin ranges from Ordovician(?), Silurian to Lower Devonian, Middle to Upper Devonian, Upper Devonian to Carboniferous, Carboniferous, Permian, and Triassic to Cretaceous. The Auburn Complex in the southeast appears to contain Carboniferous and Permian granitic rocks, and the Urannah Complex in the northeast, Carboniferous, Permian, and Cretaceous. The contacts of the serpentinite intruding the Lower Permian strata in the Marlborough area are generally faulted.

The structure of the Bowen Basin and adjoining areas reflect the complex tectonic history. Strong pre-Lower Devonian movement is indicated and there is a marked discordance between the Middle and Upper Devonian; the movements correspond to important developments elsewhere in the Tasman Geosyncline. On the eastern and western margins the Carboniferous and Permian sequences are separated by discordance. The discordance is particularly apparent in the west where strongly folded and faulted Carboniferous beds are overlain by relatively flat-lying Permian formations. The structures within the Bowen Basin (Denison Trough, Comet Ridge, Collinsville Shelf, Mimosa Syncline etc.) and the strong igneous activity in the eastern hinterland reflect developments during the Permian and Triassic. Mobility was particularly marked at the beginning of the Upper Permian in the Eungella-Cracow Mobile Belt. Uplift and folding took place in the late Triassic, and in the Jurassic sedimentation in the Great Artesian Basin began. Considerable movement occurred in the Tertiary, but little is known of the detailed geological history.

The main mineral resource of the Bowen Basin is black coal, which has been formed at many stratigraphic levels in Permian, Jurassic, and Cretaceous rocks. Most production has come from the Upper Permian Blackwater Group. Coal has also been produced from the Jurassic Injune Group and the Cretaceous Styx Coal Measures.

Although source and reservoir rocks and structure appear suitable for accumulation, particularly in the Denison Trough; so far only traces of petroleum have been found in any of the wells drilled.

Metalliferous minerals are found mainly on the margin of the basin. Gold has been mined in the Clermont and other areas; the Golden Plateau mine near Cracow is the largest producer, as it is also of silver. Copper was mined at Peak Downs in the middle 19th Century, and the area has recently been the site of considerable exploratory activity.

The Anakie Field has yielded nearly one and a half million dollars' worth of sapphire, and chrysoprase is mined near Marlborough.

INTRODUCTION

The Bowen Basin is a Permian to Triassic basin extending from Collinsville in the north to Goondiwindi in the south, where it is overlapped by Mesozoic rocks of the Surat Basin (the easternmost extension of the Great Artesian Basin). Beneath the cover the Bowen Basin may be continuous with the Sydney Basin.

The northwestern boundary is the pre-Permian Clermont Stable Block, that in the east the Eungella-Cracow Mobile Belt, where pre-Permian rocks are faulted against or overlain by steeply dipping Permian sediments, through which they penetrate as inliers. The western boundary is the Birkhead axis, which separates the Bowen Basin from the Galilee Basin. Between these boundaries lies the structural basin that Derrington (1962) called the Bowen Synclinorium: we prefer the more general term Bowen Basin.

Most of the stratigraphy of the basin has been described in detail in published reports, to which reference is made, and descriptive material is therefore kept to a minimum in this Bulletin; only rock units not adequately described elsewhere, or re-interpreted in the light of more recent work, are described here. Figure 1 lists all the main rock units in the order in which they will be discussed.

The map area (Pls 1, 2)* is largely contained within the Fitzroy and Burdekin-Townsville Regions. The physical and cultural geography of these regions is set out in a series of maps and booklets issued by the Commonwealth Department of National Development, which have been freely drawn on for the data that follow. The towns, culture, and physiographic features of the area are shown in Figure 2. The mapped area is about 150,000 sq km. The coastline extends some 250 km north and south of Mackay. Rockhampton, the largest town in central Queensland, lies 55 km east of the mapped area.

The regional survey was a joint project by the Commonwealth Bureau of Mineral Resources and the Geological Survey of Queensland. The field parties engaged in the survey are listed below.

* See also the published 1:500,000 coloured geological map of the Bowen Basin (2 sheets)

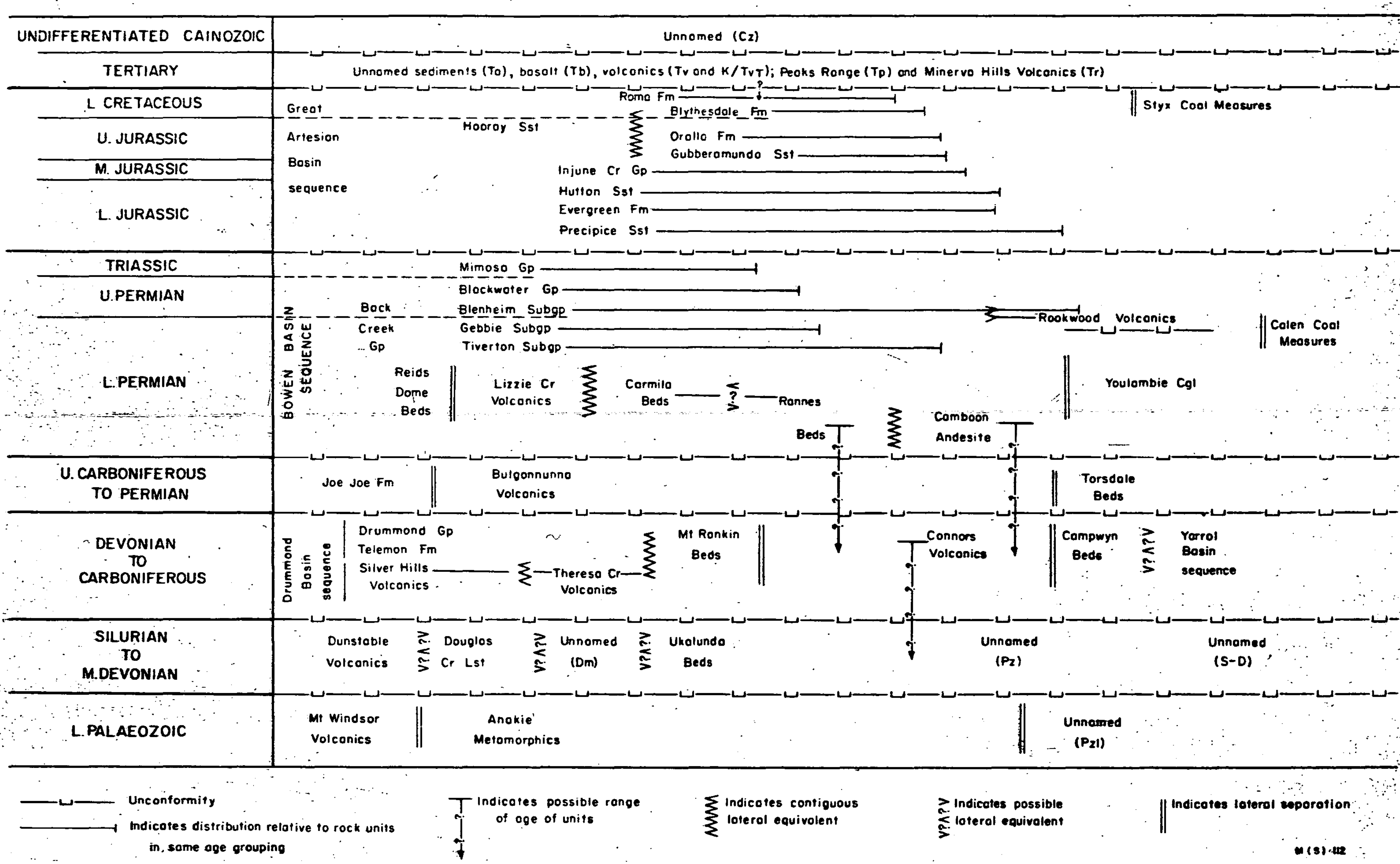
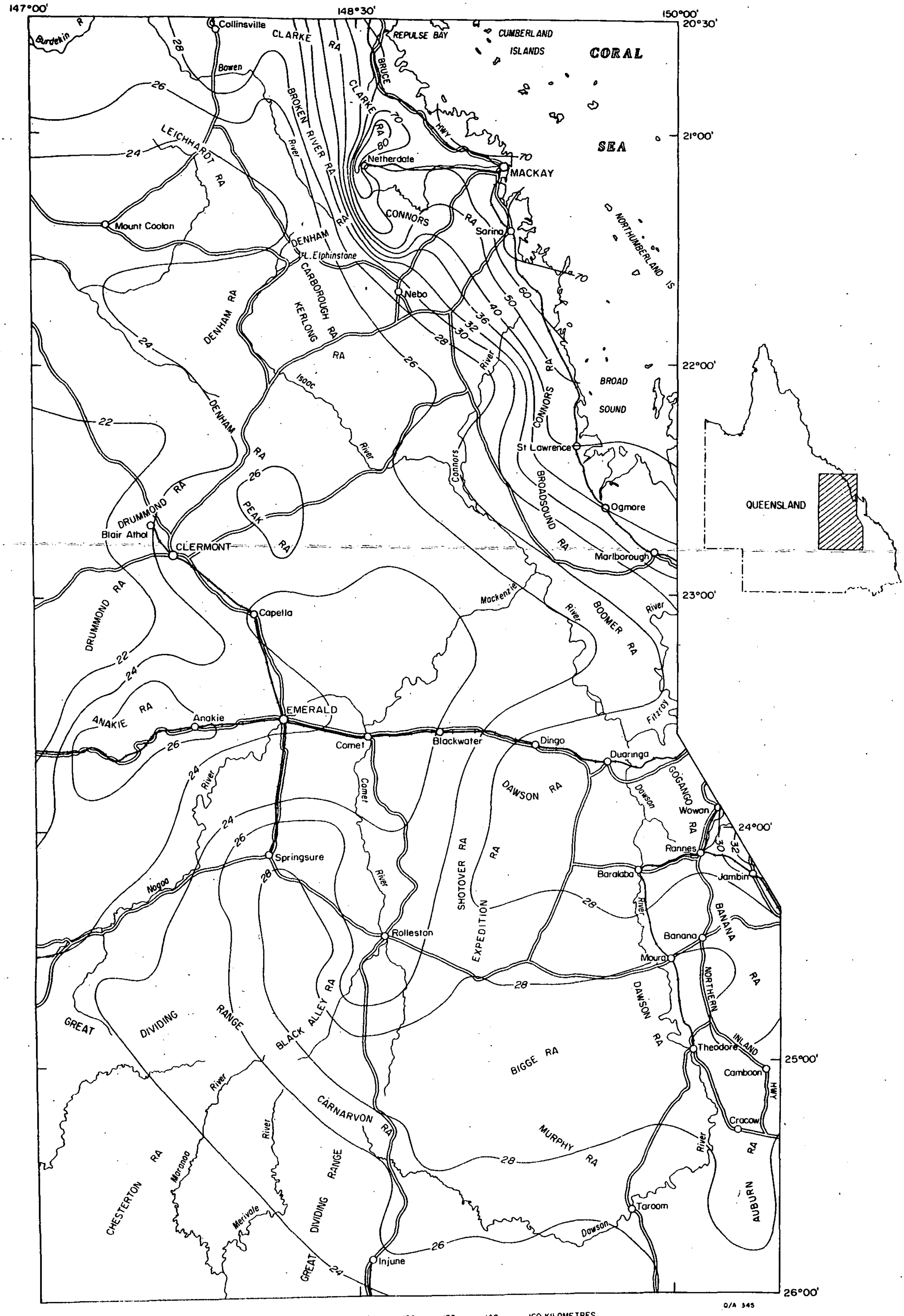


Fig.1 AGE GROUPINGS OF MAIN ROCK UNITS TO ACCOMPANY RECORD 1971/64



LOCALITY MAP Fig 2

TO ACCOMPANY REPORT 1971/64

Year	Sheet Area	Composition of Field Party
1960	Clermont	J.J. Veevers (party leader), R.G. Mollan, and M.A. Randal (BMR); R.G. Paten (GSQ)
"	Mt Coolon	E.J. Malone (party leader), D.W.P. Corbett, and A.R. Jensen (BMR); P.E. Bock and L.G. Cutler (GSQ)
1961	S. part of Bowen, & Mackay	E.J. Malone (party leader), C.M. Gregory, and A.R. Jensen (BMR); V.R. Forbes (GSQ)
	Emerald	J.J. Veevers (party leader), R.G. Mollan, and F. Olgers (BMR); A.G. Kirkegaard (GSQ)
1962	Duaringa & S. part of St Lawrence	E.J. Malone (party leader), R.G. Mollan, and F. Olgers (BMR); A.G. Kirkegaard (GSQ)
"	Mackay, S. part of Proserpine, & N. part of St Lawrence	A.R. Jensen (party leader) and C.M. Gregory (BMR); V.R. Forbes (GSQ)
1963	Baralaba & Gogango Range	F. Olgers (party leader), J.A.J. Smit, and A.W. Webb (BMR); B.A. Coxhead (GSQ)
"	Duaringa	L.V. Bastian and E.J. Malone (BMR)
"	W. part of Mundubbera, & Taroom	A.R. Jensen (party leader) and C.M. Gregory (BMR); V.R. Forbes (GSQ)
"	Springsure	R.G. Mollan (party leader) and N.F. Exon (BMR); A.G. Kirkegaard (GSQ)
1964	N.E. part of Duaringa & E. part of St Lawrence	F. Olgers (party leader) and E.J. Malone (BMR); A.G. Kirkegaard (GSQ)
"	Eddystone	R.G. Mollan (party leader) and N.F. Exon (BMR); V.R. Forbes (GSQ)

Others who visited the field area or were associated with the regional survey were M. Armin, J.M. Dickins, P.R. Evans, A. Fehr, W.J. Perry, J.A. Talent (Geol. Surv. Victoria), Professor Dorothy Hill (Qld Univ.), Beverley Houston (GSQ), A.G. McKellar (GSQ), J.E. Thompson, and Mary E. White. Planning and co-ordination was carried out by J.M. Dickins and E.J. Malone working in collaboration with J.N. Casey (Assistant Chief Geologist, Sedimentary Basins, BMR), J.E. Thompson (Supervising Geologist, Sedimentary Basins, BMR), and G.W. Tweedale (Supervising Geologist, Regional Mapping, GSQ) under the overall direction of N.H. Fisher (Assistant Director, Geology, BMR) and A.K. Denmead (Chief Government Geologist, GSQ).

Fifty-one shallow core holes were drilled for stratigraphic and palaeontological information in 1963 and 1964, and a helicopter was used in 1964 to map otherwise inaccessible parts of the area.

Authorship of this Bulletin is as follows, Malone: geology, tables, plates, figures; Dickins: Introduction, Permian palaeontology, economic geology; Dickins also collated the volume for publication.

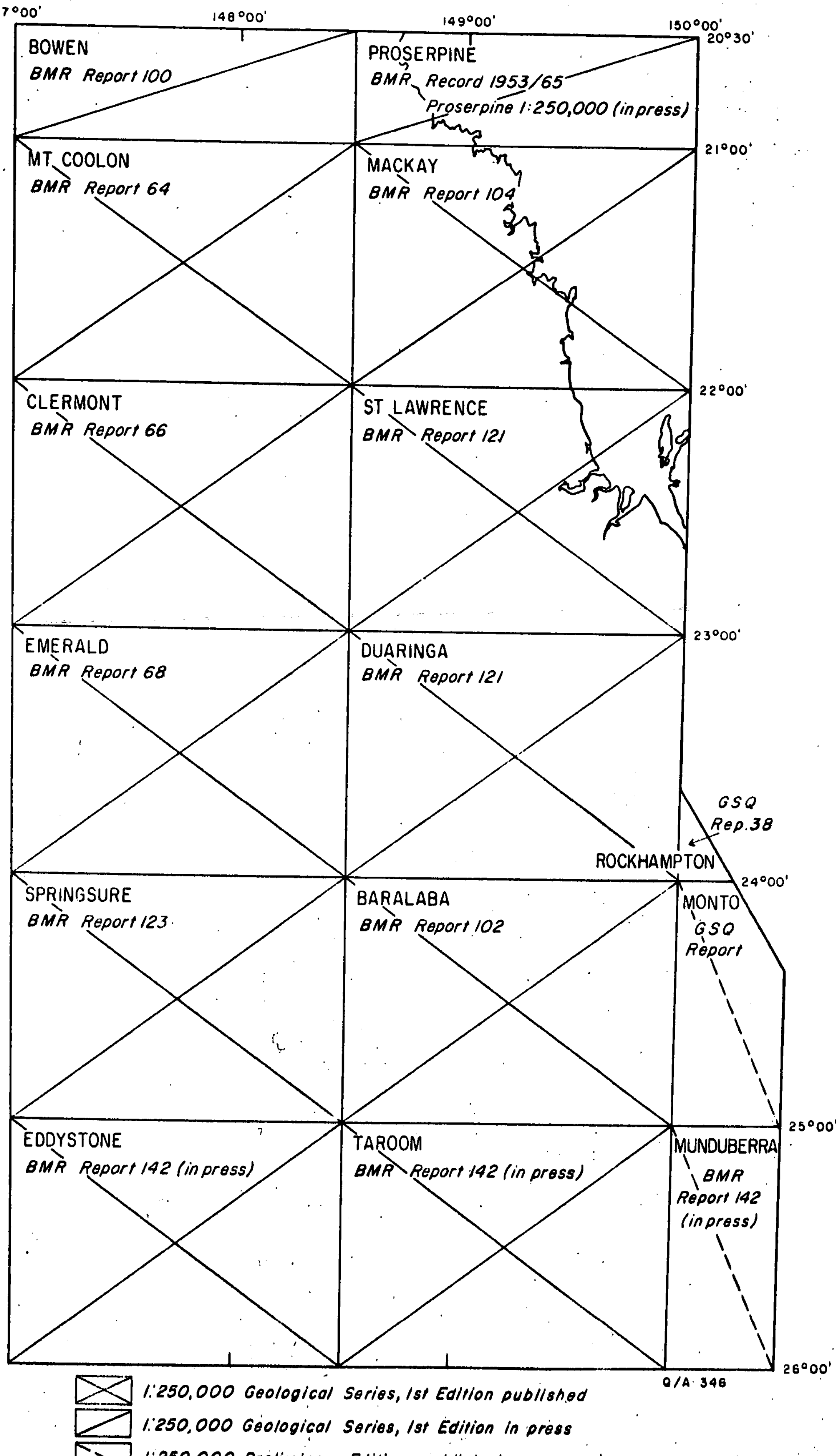
The results of the regional mapping have been or are being published in a series of reports (see Fig. 3). Coloured editions of the ten 1:250,000 Sheet areas within the map area, together with explanatory notes, have been published, or are in press or in preparation.

Much geological and geophysical work and drilling has been carried out by private companies engaged in the search for petroleum and coal. The survey has benefited greatly from collaboration with many organizations and individuals, and their help is acknowledged in the reports on individual Sheets.

Access

The area, especially near the coast, is fairly accessible (see DND, 1965). Scheduled flights serve several communities, and all are linked by a network of public and private roads. All-weather roads have been constructed near the coast, but inland many of the roads are impassable after heavy rain. Part of the area is rugged and is difficult to reach by motor vehicle.

Three railways extend from Rockhampton into or across the area; one runs south to Theodore with a spur line from Rannes to near Biloela; one west through Emerald and the third north parallel to the coast. A fourth line links Collinsville to Bowen on the coast to the north, and a fifth links Moura to Gladstone on the coast to the east.



AREAS COVERED BY BMR MAPS AND REPORTS

TO ACCOMPANY REPORT 1971/64 FIG. 3

Population and Industry

Mackay, with a population of more than 21,000, is the largest town in the area. Emerald (3050), Clermont (1750), and Collinsville (about 2000), all inland, are the only other towns with populations greater than 1000. The rural population is very sparse, except near Mackay, where sugar-cane farming supports a fairly dense population.

Cattle raising is the main industry and most of the towns exist to supply goods and services to the surrounding homesteads. Coal mining at Moura, Baralaba, Blackwater, Blair Athol, and Collinsville is contributing an increasing part of the primary production. Agriculture is mainly confined to sugar-cane farming near Mackay, and to the growing of various crops near Theodore and Baralaba. Supplemental cattle feed is grown in many small areas. Timber cutting and milling are locally important, and many of the population are employed in road and railway maintenance work.

Climate, Vegetation, and Drainage

The climate in the main is subtropical and subhumid, with a variable rainfall which falls mostly in the warmer half of the year (DND, Climate, 1965). In general, rainfall decreases to the west away from the coast: west of Mackay annual average rainfall is about 2000 mm, whereas at Emerald and Clermont it is about 625 mm.

Day temperatures range from about 25°C to 35°C during most of the year, although they are rather more extreme inland.

Average annual evaporation ranges from about 1.5 m in coastal regions to about 2.4 m inland.

The vegetation varies according to the climate and soil, and ranges from dense rain forest and lush grassland near the coast to open park and grassland inland.

Drainage is mainly towards the coast into a few large and many small rivers. Most of the area is drained by the Fitzroy River system, which includes the Mackenzie and Dawson Rivers. Some streams drain into the Burnett River in the south and the Bowen River, which joins the Burdekin, in the north. Rivers in the southwest enter the Warrego River.

Physiography

The physiographic units range from coastal plains in the northeast to inland plains, in the southwest, which merge into the Lake Eyre drainage basin (see DND, 1967a).

The coastal plains between the Eastern Highlands and the east are nowhere extensive. The highlands form an almost continuous belt of resistant rocks with summits generally between 360 and 750 m above sea level; in the Clark Range west of Mackay they rise to 1200 m. The extensive Central Plains and Lowlands correspond closely to the Bowen Basin as a geological structural entity. Resistant Mesozoic rocks form extensive tablelands in the central part of the basin (Redcliffe and Carborough Tablelands), and particularly in the south-central part (bounded by the Dawson and Expedition Ranges). The South-central Tableland slopes gradually to the south, in accordance with the structure of the Mesozoic rocks.

Previous Investigations

Geological. Before World War I, geological investigations were mainly concerned with the search for and occurrence of economic minerals, particularly coal, gold, and sapphires, and groundwater potential. Daintree, Dunstan, Jack, and Rands, of the Geological Survey of Queensland, were the principal investigators. Jack, with R. Etheridge of the Australian Museum, Sydney, also wrote a comprehensive account (1892) of the geology and palaeontology of the whole Colony, in which the threefold division of the Permian of the Bowen Basin was first proposed. Later work, including our own, has confirmed the value of this subdivision in understanding the development of the basin.

Between the wars, the search for petroleum, stimulated by the discovery of gas at Roma in 1900, assumed considerable importance, and the work of officers of the Survey, notably Ball, Jensen, Morton, and Reid, was supplemented by that of petroleum exploration companies. Shell (Queensland) Development Pty Ltd, in particular, undertook some detailed surface mapping, and followed it with drilling - unfortunately unsuccessful. Indeed, despite present production of gas in the Roma district, the early promise of the area has yet to be fulfilled.

Since World War II, the search for both petroleum and coal has been intensified. Geophysical surveys were made by both the Bureau of Mineral Resources and private companies: companies have undertaken much geological work; and on the initiative of Professor Dorothy Hill, the University of Queensland, and later the Geological Survey of Queensland, undertook many geological and palaeontological studies. Finally, in 1960, a survey of the entire region was begun by the Bureau of Mineral Resources and the Geological Survey of Queensland. It is this survey that is mainly reported in this volume.

No petroleum has been produced commercially from the area covered by this Bulletin, but the coal resources, particularly of coking coal, are among the most important in the whole of Oceania and southeast Asia.

Aeromagnetic. During 1961 to 1963 an aeromagnetic survey was undertaken by the BMR (Wells & Milsom, 1966). They reduced the recorded magnetic profiles by about five and displayed alternate profiles on a geological base map at 1:250,000. They drew the estimated depth to magnetic basement contours at a scale of 1:1,000,000 and these are reproduced along with the gravity results in Plate 3.

The estimated magnetic basement agrees reasonably well with the main structural units. The Nebo Synclinorium, the Mimosa Syncline, and the Styx Basin and Strathmuir Synclinorium are outlined. In the Nebo Synclinorium where the calculated magnetic basement is 9600 m, pre-Permian structure may be indicated. Similarly, the deep magnetic basement in the southwest may reflect pre-Permian, that is, pre-Bowen Basin structure.

Gravity. Previous gravity surveys are summarized in Lonsdale (1965) and Darby (1966), and the results are shown in Plate 3 compiled from published BMR 1:500,000 maps and from preliminary 1:250,000 maps (Springsure and Eddystone). The Strathmuir and Nebo Synclinoriums, the Mimosa Syncline, and the Denison Trough are outlined by negative gravity anomalies, whereas the Connors Arch, Gogango Overfolded Zone, and Auburn Arch in the Eungella-Cracow Mobile Belt are defined by positive anomalies. The Comet Ridge and Anakie Inlier are also marked by positive anomalies. The Bouguer gravity map, however, suggests that the boundary between the Collinsville Shelf and the Nebo Synclinorium possibly lies to the west of the boundary shown in Plate 3. The Clermont Block and its assumed continuation under the western part of the Bowen Basin and Great Artesian Basin shows a complex pattern of positive and negative anomalies, which apparently reflect pre-Permian structure.

Seismic. A great deal of seismic work has been done, particularly in the southwest and south, much of it since 1960. Much is unpublished. Early work was carried out by Shell (Qld) Development (1952) and the BMR (Smith, 1951). The BMR reconnaissance survey (Robertson, 1961, 1965) was particularly useful in outlining the structure within the basin along an east-west line between Emerald and Duaringa.

The seismic surveys have been particularly useful in delineating structure, but in most areas the surveys are not sufficiently detailed to delineate more than one or two horizons. The coal measures of the Blackwater Group are a major reflecting horizon and, while this reflection has tended to mask lower horizons, it has offered good control for determining the overall structure of the basin.

LOWER PALAEOZOIC

Rock units assigned to the Lower Palaeozoic comprise the Anakie Metamorphics in the Anakie Inlier in the west, the Mount Windsor Volcanics in the northwest corner, and metamorphics cropping out around Marlborough in the east.

Anakie Metamorphics

Jensen (1921c) used the term Anakie Series for the granite, porphyry, schist, and slate near Anakie. Later, the name Anakie Metamorphics was applied to Lower Palaeozoic rocks extending from Anakie to southwest of Collinsville on the Geological Map of Queensland (Hill, ed, 1953; Hill & Denmead, eds, 1960).

The Anakie Metamorphics crop out in a belt extending north-northwest from Anakie to Rosetta Creek, and in the core of the Telemon Anticline, west of Springsure. The largest area of outcrop is west of Clermont, where the metamorphics form high gently rounded closely spaced hills with a deeply incised dendritic drainage. Near Anakie, they crop out in prominent strike ridges south of the contact with the Retreat Granite. The topography is more subdued east of Clermont and north of Miclere Creek, where low rubble-covered hills rise about 15 m above the surrounding alluvial and black-soil plains. In the north the metamorphics are lateritized in places. The laterite profile has been dissected into scattered low mesas.

Mapping of the Anakie Metamorphics was confined to locating the main boundaries, mainly by air-photo interpretation. Few outcrops were examined in detail and few specimens were examined in thin section. The main rock types include mica schist, quartz-mica schist, knotted schist, phyllite, banded phyllite, slate, and quartzite. Lenses of unfossiliferous crystalline limestone, 6 m thick and up to 150 m long, are interbedded with slate northwest of Anakie, and what appears to be metamorphosed pillow lava crops out about 19 km north of Anakie. The widespread quartz veins and reefs in the metamorphics are the source of the abundant quartz rubble covering areas of poor outcrop. The inlier in the core of the Telemon Anticline consists of strongly foliated coarse quartz-feldspar-mica gneiss interbedded with garnetiferous muscovite schist, biotite-quartz phyllite, schist, and sheared diorite and other igneous rocks.

Most of the lutites in the Anakie Metamorphics are closely foliated. Two foliation directions, 080° and 340° (Veevers, Mollan, Olgers, & Kirkegaard, 1964a) were noted west of Clermont, but other foliation directions are dominant elsewhere. The quartz veins are concordant with the foliation in places (Veevers, Randal, Mollan, & Paten, 1964b). Foliation in the Telemon Anticline Inlier strikes northeast and dips southeast.

Little is known of the structure of the Anakie Metamorphics. The formation is exposed in the elongate Anakie Inlier separating the Drummond Basin to the west from the sequence of thick Devonian-Carboniferous sedimentary rocks to the east. At times during the Devonian-Carboniferous, sedimentation probably extended across the inlier, particularly near Miclere Creek; farther south, the inlier supplied detritus to the Drummond Basin.

At the northern end of the inlier the Anakie Metamorphics are separated by a narrow strip of alluvium from lower Middle Devonian Ukalunda Beds. The boundary is arbitrary; scattered trends indicate that the Ukalunda Beds trend south into the Anakie Metamorphics, but the two units cannot be distinguished because of poor outcrop. Blocks of fossiliferous lower Middle Devonian rocks were mapped south of Clermont and in the Nogoa Anticline; their relationships to the Anakie Metamorphics are obscure, but presumably they rest unconformably on the metamorphics. However, the Anakie Metamorphics, as mapped, probably include some Middle Devonian rocks. The Anakie Metamorphics are unconformably overlain by the Drummond Basin sequence and are intruded by the Retreat Granite.

No fossils have been found in the Anakie Metamorphics. An age of 450 m.y. was determined (A.W. Webb, pers. comm.) on muscovite from a mica schist about 22 km southwest of Clermont. This was probably the age of metamorphism. A similar age was determined (A.W. Webb, pers. comm.) for the granite in the core of the Telemon Anticline. These results indicate that the Anakie Metamorphics are Ordovician or older.

Lower Palaeozoic Metamorphics (Pzl)

These rocks crop out around Marlborough and extend east into the adjacent Rockhampton and Port Clinton Sheet areas. The outcrops within the map area are described in Malone, Olgers, & Kirkegaard (1969); the outcrops to the east are described in Kirkegaard, Shaw, and Murray (in prep.). The metamorphics include sediments and interbedded volcanics or minor intrusives which have undergone regional metamorphism and subsequent thermal and dynamic metamorphism. Rock types include quartz-mica schist, talc schist, quartzite, hornfelsed quartz-mica schist, pyroxenite, and garnetiferous quartz-mica schist; interbedded igneous rocks include uralitized metagabbro and schistose altered andesite or basalt.

The structure of the metamorphics is unknown. In many outcrops, they have a prominent steeply dipping foliation trending east or northeast. The metamorphics were intruded by serpentinite, though most of the contacts are faulted; the metamorphics and serpentinite form a block which is faulted against Lower Permian rocks to the west and is intruded by Permian gabbro and granite.

The age of the metamorphics is unknown. They are thought to be Lower Palaeozoic because their grade of metamorphism is much higher than that of fossiliferous Upper Silurian sediments and volcanics cropping out 48 km south of Marlborough.

Mount Windsor Volcanics

The Mount Windsor Volcanics occupy a small area in the northwest corner of the map area. They are much more extensive to the north and west, and are described in Wyatt, Paine, Clarke, Gregory, & Harding (1967) and Paine, Gregory, & Clarke (in prep.). They consist of fine-grained porphyritic rhyolite and rhyolite breccia, rhyodacite, dacite, andesite, and minor sediments, and are strongly jointed and cut by numerous northeasterly trending faults. The volcanics are sheared and mylonitized in fault zones and are strongly contact metamorphosed by the Ravenswood Granodiorite. They are unconformably overlain by the Bulgonunna Volcanics.

The Mount Windsor Volcanics are regarded as Lower Palaeozoic because they are older than the Ravenswood Granodiorite which has been dated isotopically at about 420 m.y., that is, probably Silurian (A.W. Webb, pers. comm.).

SILURIAN TO MIDDLE DEVONIAN

The rock units deposited in Silurian to Middle Devonian times comprise unnamed Upper Silurian to Lower Devonian rocks (S-D) south of Marlborough in the east; the lower Middle Devonian Ukalunda Beds in the northwest; the Lower or Middle Devonian Dunstable Volcanics in the Nogoa Anticline, west of Springsure; the Middle Devonian Douglas Creek Limestone and unnamed equivalents (Dm) south and southeast of Clermont; and a small block of unnamed metamorphics (Pz) 40 km southeast of Theodore.

Silurian-Devonian (S-D)

The oldest fossiliferous rocks in the area are unnamed volcanics, chert, limestone, and minor clastics cropping out about 40 km south of Marlborough. They are described in Malone et al. (1969), and their extension to the east is described in Kirkegaard, Shaw, & Murray (in prep.). They are exposed over about 150 sq km in the core of the Craigilee Anticline and in smaller inliers to the west and southwest. Volcanics predominate; they include keratophyre, altered trachyte and spilite, andesite, andesitic and spilitic crystal and lithic tuffs, and volcanic conglomerate. Light green chert predominates in some areas, and in places it is associated with purple mudstone and conglomerate. Thick beds of limestone or lenses of limestone are interbedded with the volcanics in three localities. About 53 km south of Marlborough, lenses of thin to thick-bedded fossiliferous limestone, up to 30 m thick, are interbedded with flows, tuffs, and fossiliferous calcareous tuffaceous sandstone. The fossils from this locality are Upper Silurian (Mackellar, Appendix 7, in Malone et al., 1969). In the other two localities the limestone is recrystallized and metamorphosed to marble in places, but contains some very fossiliferous bands; the fossils indicate a Silurian to Lower Devonian age (Hill, Appendix 4, in Malone et al., 1969).

No fossils have been found in the small inliers west and southwest of the main area of outcrop. The rocks in the inliers are regarded as Silurian-Devonian because they consist mainly of volcanics, including abundant keratophyre, which are lithologically similar to the volcanics associated with the fossiliferous beds.

The dominance of massive volcanics conceals the structure of the Silurian-Devonian rocks, though gross changes of lithology suggest a regional easterly dip in places. The limestone beds near the northeast corner of the main outcrop area are closely jointed and sheared, and tightly folded. The style of folding is apparently related to the thickness of the beds: the thick-bedded limestone is folded into very steep almost symmetrical folds; while the thin-bedded limestone is folded and cross-folded into disharmonic structures involving about 30 m of section, complicated by small-scale folds with an amplitude of about 30 cm. Elsewhere the limestone beds are steeply dipping. The Silurian-Devonian rocks were folded before the overlying Upper Devonian to Lower Carboniferous sediments were laid down unconformably on them. The magnitude of the unconformity is clearly visible east of the Upper Silurian fossil locality, where the Silurian-Devonian rocks dip vertically and strike northeast, and the overlying sediments dip east at about 70°.

The Silurian-Devonian rocks were partly emergent during the Devonian-Carboniferous sedimentation. Clasts of Silurian-Devonian limestone are contained in a conglomerate, locally basal to the Devonian-Carboniferous sequence, about 1½ km east of the folded limestone outcrops. The succeeding sediments and volcanics onlapped the Silurian-Devonian rocks so that Lower Carboniferous, Upper Carboniferous, and Lower Permian rocks are in contact with the Silurian-Devonian rocks in places. The inliers of Silurian-Devonian rocks to the west are faulted against the Lower Permian or older Rannes Beds and are unconformably overlain by the late Lower Permian Rookwood Volcanics and the Upper Permian Boomer Formation.

The thickness of the Silurian-Devonian rocks is not known, but they are obviously thick and are more extensive than their area of outcrop. They are regarded as Upper Silurian to Lower Devonian in age.

Ukalunda Beds

The Ukalunda Beds occupy the northern end of the Anakie Inlier. They were distinguished from the Anakie Metamorphics during the mapping of the southern half of the Bowen Sheet area (Malone et al., 1966) when the fossils collected from many localities in the Ukalunda Beds indicated that they were of lower Middle Devonian age, much younger than the Ordovician or older Anakie Metamorphics. The extension of the Ukalunda Beds to the south into the Mount Coolon Sheet area was earlier described as part of the Anakie Metamorphics (Malone et al., 1964). The name Ukalunda Beds (Jack, 1889) was revived by Malone et al. (1966), who described the unit and discussed its stratigraphic position.

The boundary between the Ukalunda Beds and the Anakie Metamorphics as shown on the geological map is arbitrary as both units are poorly exposed in the western part of the Mount Coolon Sheet area.

Five rock associations can be recognized in the Ukalunda Beds, but as the beds are poorly exposed it is not known whether they have any stratigraphic significance. The approximate distribution of the five units, A, B, C, D, and E, is shown in Figure 4.

Unit A

Unit A is the most widespread and possibly the youngest unit. It consists mainly of siltstone and arenite. The siltstone is closely jointed or cleaved, deeply weathered, and commonly ferruginized; it ranges from grey to buff, pink, and red, or mottled red and white, according to the degree of weathering. The arenite is lithic or sublabile and commonly feldspathic; it is generally fine to medium-grained and in most places has a calcite and chlorite cement. The fine arenite is generally closely jointed. Unit A includes thinly interbedded siltstone and arenite and interlaminated and varicoloured siltstone and claystone. The siltstone contains thin beds of fossiliferous silicified limestone in a few places; the fossils are poorly preserved, but are similar to some in other collections from the Ukalunda Beds.

Unit A has been contact metamorphosed to quartz-muscovite-schist, hornfels, and spotted and lineated siltstone, and in places it has been silicified, epidotized, and locally mineralized.

Unit B

Unit B consists of jointed quartz-veined and silicified quartz sandstone grading in places into quartz-pebble conglomerate. The sandstone is metamorphosed to quartzite in one place; in general, the quartz grains are cracked, broken, strained, and re-oriented, and in places the sericite flakes in the matrix are aligned.

Unit C

Unit C consists of (i) alternating and generally well bedded fine to coarse hard calcareous labile greywacke and thin-bedded grey, green, and brown siltstone and dark shale, slump folded in places; (ii) thick lenses of blue-grey pebble to cobble conglomerate interbedded with lithic arenite; (iii) banded grey-green thick-bedded silicified limestone, biostromal in part; and (iv) a sequence of green medium-grained tuff, coarse crystal tuff, grey-green siltstone, tuffaceous arenite, thin rhyolite flows, volcanic agglomerate, and thick beds of partly volcanolithic pebble to cobble conglomerate interbedded with thin-bedded fine and coarse tuff. (Subunit 'iv' was referred to Devonian-Carboniferous Volcanics in Malone et al., 1966). The calcareous labile greywacke of subunit (i) contains feldspar grains and lithic fragments which include devitrified glass and flow-banded volcanics. Flow-banded rhyolite porphyry and uralitized trachyandesite flows or sills are interbedded in unit C in places. Unit A overlies unit C where they are in contact.

Unit D

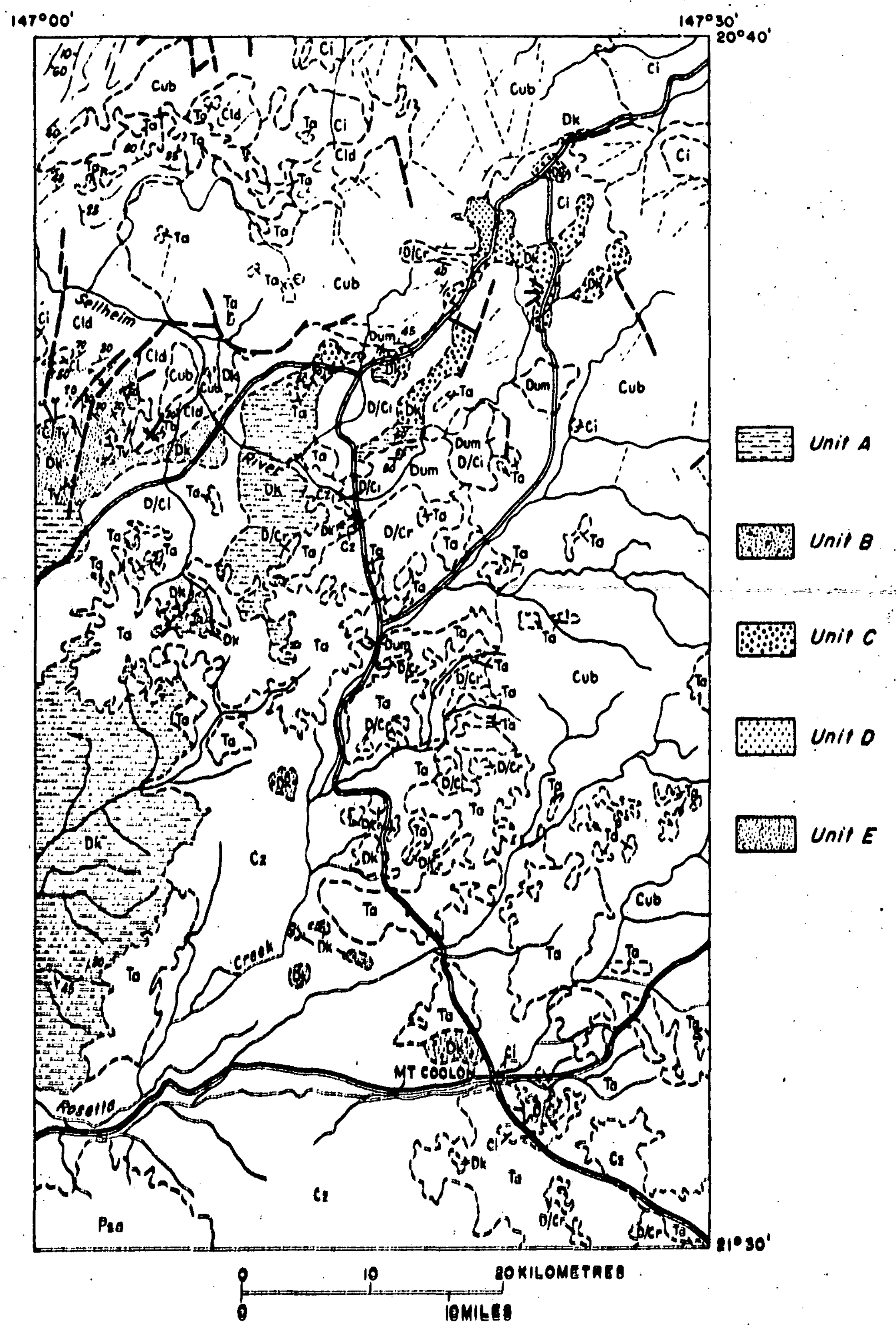
Unit D occupies the smallest area. It consists of (i) closely jointed khaki to dark grey siltstone, which is calcareous and fossiliferous in places and commonly contains rounded non-jointed cobbles of siltstone; (ii) beds and lenses up to 15 cm thick of grey fossiliferous limestone and small blocks of compound corals which are interbedded with calcareous siltstone or calcareous lithic arenite; (iii) thin-bedded micaceous coarse siltstone and fine arenite; (iv) soft olive-grey thin-bedded siltstone interbedded with dense grey to dark grey pyritic impure chert, which in places encloses pods of limestone; and (v) medium to coarse lithic arenite, hardened and veined by quartz in places.

Unit E

Unit E consists of siltstone, lithic arenite, quartz sandstone, and conglomerate. The conglomerate is a distinctive rock consisting mainly of white quartz pebbles in a red siliceous matrix. The conglomerate and associated quartz sandstone resemble unit B. The siltstone is closely jointed, khaki or grey, generally calcareous and fossiliferous, and contains pods of foetid limestone.

The best preserved and most abundant fossil faunas were collected from similar rock types in units D and E. However, only one of the species present in unit E is present in unit D. Both faunas are Eifelian (lower Middle Devonian).

The Ukalunda Beds are intruded by large granodiorite intrusions and are extensively contact metamorphosed; minor gold, bismuth, arsenic, silver, lead, and copper mineralization occurs in the contact zones in places. They have undergone low-grade regional metamorphism which has



For explanation of letter symbols see published 1:500,000 geological map

F55/A 145

DISTRIBUTION OF THE UKALUNDA BEDS

Fig.4

TO ACCOMPANY RECORD 1971/64

produced the common jointing and shearing, and in places a schistose alignment of secondary sericite flakes in the argillaceous laminae. A zone of shearing in units A and E strikes north to northeast along the western margin of the Ukalunda Beds, parallel to the Drummond Basin. The shearing has produced phyllite, sheared siltstone, and interbedded unaltered fine arenite and sheared siltstone containing aligned sericite flakes. The shear cleavage is approximately parallel to the axial planes of folds in the Drummond Basin and possibly developed in response to the stress which folded the Drummond Basin sequence.

The Ukalunda Beds are moderately tightly folded into structures with a fairly large amplitude; few tight minor folds were noted. Dips are mainly between 30° and 70°. The Ukalunda Beds are unconformably overlain by the Drummond Basin sequence to the west, by the Mount Rankin Beds to the east, and by the Bulgonunna Volcanics to the northeast. The unconformity at the base of the Bulgonunna Volcanics is exposed at several places. The unconformities at the base of the Drummond Basin sequence and at the base of the Mount Rankin Beds are not exposed, but can be reliably inferred from the regional structure and from the difference in the degree of metamorphism and difference in age between the Ukalunda Beds and the younger units.

Dunstable Volcanics

The name Dunstable Volcanics (Hill, 1957) was revised in Mollan, Dickins, Exon, & Kirkegaard, 1969). The volcanics are exposed in a small northeasterly trending fault-bounded inlier in the northern culmination of the Nogoa Anticline. Their area of outcrop and relationships to the overlying units are illustrated in Figure 5. The Dunstable Volcanics consist of tough green andesitic lavas and pyroclastics which contain lenses of partly recrystallized coralline limestone and splintery black and olive-green cherty shale. The Dunstable Volcanics are resistant to weathering, and this serves to distinguish them from the overlying, generally deeply weathered, Silver Hills Volcanics. Fossils from the limestone lenses are probably lower Middle Devonian (Hill, Appendix 3 in Veevers et al., 1964a); as the fossiliferous lenses are near the top of the exposed section, the age of the lower part of the volcanics is not known. A thickness of about 450 m of Dunstable Volcanics is exposed in the Nogoa Anticline, but neither the top nor bottom is exposed.

Douglas Creek Limestone and Equivalents(?)

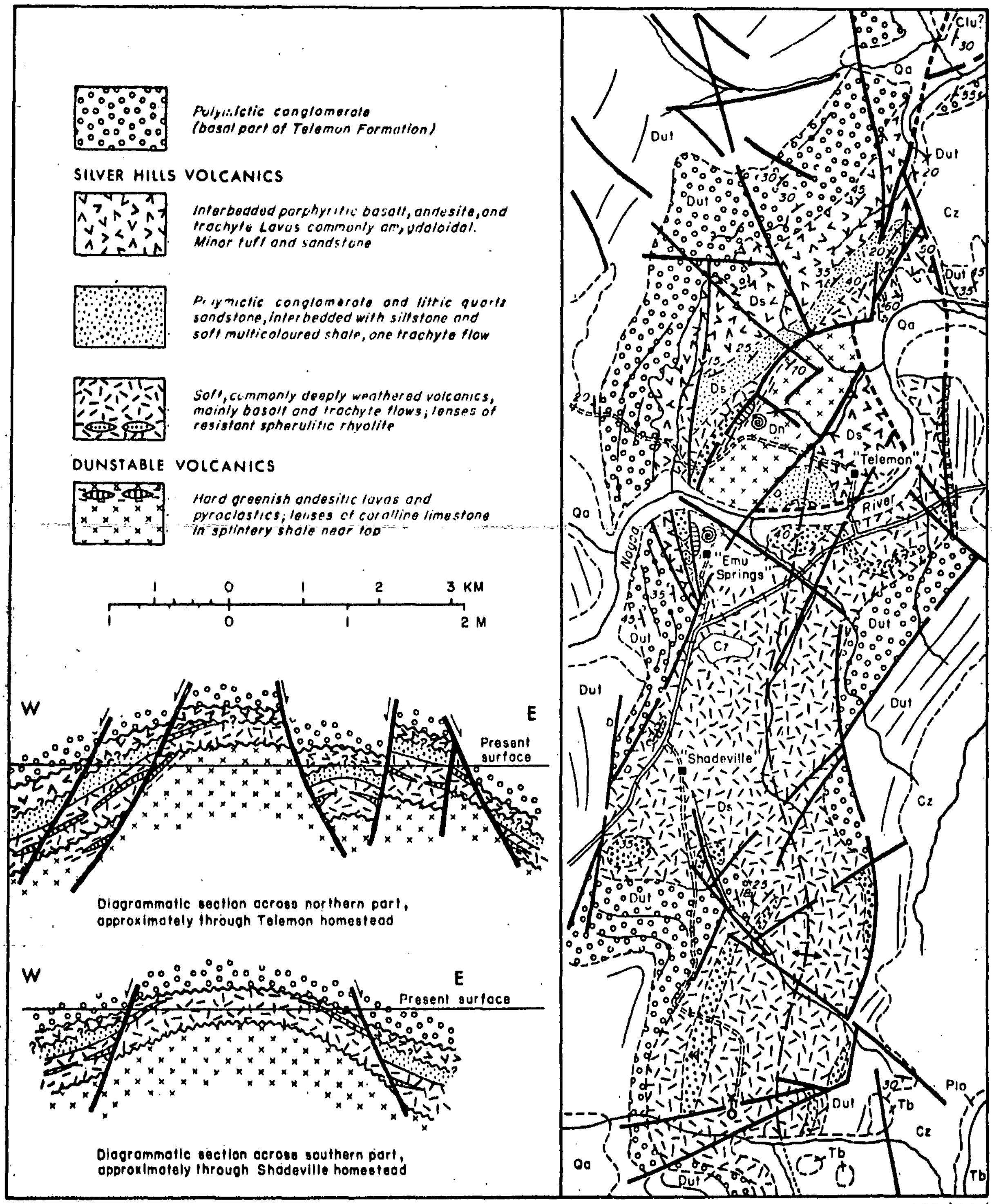
The Douglas Creek Limestone is reviewed in Veevers et al. (1964b). It consists of blue-grey fine-grained massive and well jointed richly fossiliferous limestone cropping out in a small area 8 km south of Clermont. The fossils indicate a lower Middle Devonian age, probably upper Couvinian (Hill, 1939; Jones, 1941).

The unnamed Middle Devonian sediments south of the Douglas Creek Limestone outcrop include three small outcrops of well bedded thin-bedded grey to brown micaceous siltstone and one small area of limestone rubble. A thickness of about 30 m of siltstone is exposed in the largest outcrop. The siltstone contains fossils which indicate a lower Middle Devonian or possibly Lower Devonian age (Veevers et al., 1964b).

Middle Devonian sediments (the 'undifferentiated Palaeozoic sandstone and siltstone' of Veevers et al., 1964b) crop out in a narrow strip 24 km southwest of Clermont. They are thrust-faulted against the Anakie Metamorphics, faulted against the Theresa Creek Volcanics, and intruded by monzonite. The sequence consists mainly of fine to medium-grained cross-bedded mauve calcareous arkosic sandstone and laminated red-brown micaceous siltstone; the sediments contain angular detritus up to 15 cm across derived from the Anakie Metamorphics. Also present are tuff, coarse recrystallized limestone, and a coarse basic flow or intrusive. These rocks are tentatively regarded as Middle Devonian; they could be part of the Theresa Creek Volcanics.

The Douglas Creek Limestone and Middle Devonian sediments rest unconformably on the Anakie Metamorphics. The unconformity is not exposed, but is clearly indicated by the difference in metamorphic grade and by the absence of quartz veins in the Middle Devonian sediments and by their abundance in the Anakie Metamorphics. The Middle Devonian sediments are overlain, apparently conformably, by the Theresa Creek Volcanics.

The second area of unnamed Middle Devonian sediments is located 29 km west-southwest of Emerald (Veevers et al., 1964a). The rocks exposed are siltstone, pebbly quartz grit, tuff, shale, limestone, and rhyolite. The limestone contains corals which indicate a Middle Devonian age (Hill, Appendix 3, in Veevers et al., 1964a). The base of the sequence is not exposed; it is unconformably overlain by subhorizontal Permian sediments.



For explanation of symbols see 1:250,000 Springsure Geological map

G55/A3/80

Fig. 5 DISTRIBUTION OF THE DUNSTABLE VOLCANICS

TO ACCOMPANY RECORD 1971/64

The Middle Devonian rocks crop out at the northern and southern ends of the Anakie Inlier and near the eastern margin of the inlier. All the sediments are of about the same age and were possibly deposited in a sea which was bounded to the west by the Anakie Metamorphics. Vulcanism was dominant in the south (Dunstable Volcanics) and was relatively rare in the north.

Unnamed Palaeozoic Metamorphics (Pz)

Granulite and metaquartzite crop out in a small area 40 km southeast of Theodore (Mollan, Forbes, Jensen, Exon, & Gregory, in press). They overlie and were presumably metamorphosed by the Auburn Complex, although the contacts are not exposed. The metamorphics contain no intrinsic evidence of their age. They are older than the igneous rocks which have been dated isotopically at about 300 m.y. (A.W. Webb, pers. comm.). The metaquartzite is apparently a metamorphosed quartz sandstone and the granulite is a metamorphosed arkose.

DEVONIAN TO CARBONIFEROUS

In Devonian to Carboniferous times, sediments and volcanics were laid down in three large sedimentary basins; the Drummond Basin to the west of the Anakie Inlier; the basin to the east of the Anakie Inlier in which the Mount Rankin Beds were deposited; and the Yarrol Basin in the eastern part of the map area. Outside these three basins, the Theresa Creek Volcanics were laid down on the Anakie Inlier, possibly at the same time as and perhaps continuously with the Silver Hills Volcanics; the Campwyn Beds were deposited in what was probably the northern extension of the Yarrol Basin; and the Connors Volcanics were laid down to the west of the Yarrol Basin. The Connors Volcanics are older than Upper Carboniferous and are tentatively regarded as equivalents of the Campwyn Beds because of the similarity in lithology and structure and are therefore included with the Devonian to Carboniferous rocks; they could be older and may be equivalents of the Silurian-Devonian rocks.

Volcanics, which may be equivalent to the Connors Volcanics, are included in the Camboon Andesite which ranges from Upper Carboniferous or older to lower Permian. The age of the older part of the Camboon Andesite is based on the isotopic age of certain intrusive igneous rocks. The Upper Carboniferous or older part of the Camboon Andesite and the younger Lower Permian part have not been mapped separately.

Devonian-Carboniferous rock units of the Clermont Block are briefly described in Table 1 and those of the Eungella-Cracow Mobile Belt in Table 2.

Drummond Basin Sequence

The exposed Drummond Basin is an arcuate structure trending northwest from a point about 30 km southwest of Springsure for about 110 km to where it swings nearly north. The basin lies to the west of the map area about the latitude of Mount Coolon, but reappears in the northwest where it trends northeast. The regional geology of the Drummond Basin has been described by Olgers (in prep.). Parts of the Drummond Basin, which lie within the map area are described in the following reports: Veevers et al. (1964a, b), Mollan et al. (1969), and Malone et al. (1964, 1966).

The sequence in the southern part of the Drummond Basin comprises the Silver Hills Volcanics, Telemon Formation, Mount Hall Conglomerate, Raymond Sandstone*, and Ducabrook Formation in order of decreasing age; the youngest three formations constitute the Drummond Group. In the northern part of the Drummond Basin the Drummond Group was not divided into formations. Apparently, no equivalents of the Silver Hills Volcanics are present in the north, though the sequence probably includes equivalents of the Telemon Formation.

The Silver Hills Volcanics were probably extruded in part before the downwarping of the Drummond Basin began, and were certainly deposited over a greater area than the overlying sedimentary sequence. The abundance of reworked material from the Silver Hills Volcanics in the Telemon Formation indicates that a large area of volcanics was being eroded during deposition of the Telemon Formation. The Silver Hills Volcanics, Theresa Creek Volcanics, and the volcanics of the Mount Rankin Beds may be remnants of an acid to intermediate volcanic province which covered most of the Clermont Block in the Upper Devonian.

The boundary between the Telemon Formation and the underlying Silver Hills Volcanics corresponds with a marked lithological change from a volcanic sequence to a predominantly sedimentary unit, which was partly derived from older volcanics, but which also includes subordinate volcanic rocks. The boundary marks the start of deposition in the Drummond Basin. The disconformity and local slight angular unconformities between the Telemon Formation and the overlying formations are much less significant; they correspond with epeirogenic movements or changes in the rate of subsidence.

* Name changed to Raymond Formation by Olgers (in prep.).

The lithology of the Telemon Formation is similar to that of the Ducabrook Formation, and it appears that the mature quartz-rich sediments of the intervening Mount Hall Conglomerate and Raymond Sandstone represent only a temporary change in the depositional environment. Despite the presence of a disconformity at the top of the Telemon Formation it might be better to include it in the Drummond Group because of the lithogenetic unity of the sequences, rather than excluding it, as has generally been the case. This is why the Drummond Group has not been subdivided in the northern part of the Bowen Basin.

The Mount Hall Conglomerate and Raymond Sandstone are closely related, and the former is essentially a conglomerateric phase developed locally at the base of the Raymond Sandstone. Their relationships may best be expressed by referring to them as the Snake Range Subgroup (originally Snake Range Group, SQD, 1952; Hill, 1957). The suggested nomenclature for the Drummond Basin sequence would be

	(	Ducabrook Formation
Drummond	(Snake Range	(Raymond Sandstone
Group	(Subgroup	(Mount Hall Conglomerate
	(	Telemon Formation
		- - - - - -
		Silver Hills Volcanics

Mount Rankin Beds

The Mount Rankin Beds is the name proposed for the Upper Devonian to Lower Carboniferous volcanic and sedimentary rocks cropping out east of the Anakie Inlier. The use of this name was foreshadowed in Veevers et al. (1964b). The informal term 'Beds' is used since no further work has been done in the type area since 1960 (Veevers et al., 1964b).

The name is derived from Mount Rankin (grid ref. 60702193) in the Clermont Sheet area. The type area is west, north, and east of Mount Rankin, some 55 km north-northeast of Clermont. The Mount Rankin Beds crop out discontinuously in a belt extending from about 30 km northeast of Clermont to 60 km north of Mount Coolon, in the Clermont, Mount Coolon, and Bowen Sheet areas.

The beds consist of porphyritic rhyolite, dacite, sodic pitchstone, andesite, acid and intermediate pyroclastics, including agglomerate, volcanic conglomerate and lapilli, crystal and lithic tuff, and sediments, including tuffaceous arenite, siltstone, and conglomerate. The rhyolite exhibits regular flow banding and less commonly contorted flow banding, and is spherulitic in places. It contains numerous veins and irregular masses of quartz. The flows are possibly terrestrial in part; the pyroclastics and sediments are generally well bedded and were apparently laid down under water. The sediments consist mainly of volcanic detritus. They include tough fine to medium-grained dark quartz-poor feldspathic and lithic tuffaceous arenite; thin-bedded brown, grey, and colour-banded siltstone; fine to coarse and pebbly feldspatholithic sandstone; pebble to cobble conglomerate; fossiliferous calcareous sandstone; and minor quartz sandstone. Conglomerate generally occurs in beds and lenses and grades laterally into arenite. The fossiliferous sandstone and the quartz sandstone occur only in the Mount Wyatt Beds at the base of the Mount Rankin Beds in the north and reflect a marine transgression in that area; the bulk of the Mount Rankin Beds were deposited in fresh water.

The thickness in the type area was estimated to be about 4800 m. The Lower Carboniferous fossil plants in the top 300 m include Lepidodendron, Lepidophyllum, and Lepidostrobus - all cf L. aculeatum Sternberg - and Stigmaria ficoides Brong. An Upper Devonian brachiopod, Cyrtospirifer cf. reidi Maxwell, and plants including Leptophloeum australe. Protolepidodendron, psilophytes, and Stigmaria occur in the Mount Wyatt beds at the base of the Mount Rankin Beds in the north. The fossils indicate that the Mount Rankin Beds range from Upper Devonian to Lower Carboniferous.

The Mount Rankin Beds are unconformable on the Anakie Metamorphics and Ukalunda Beds; they are unconformably overlain by the Upper Carboniferous Bulgonunna Volcanics and by Permian sediments. The volcanics at the base of the Mount Rankin Beds in the type area are considered to be part of the same Upper Devonian volcanic province as the Silver Hills and Theresa Creek Volcanics. The northern limit of this volcanic province is about the latitude of Mount Coolon. North of Mount Coolon both the Drummond Basin sequence and the Mount Rankin Beds consist mainly of clastics, derived from volcanic rocks, with some tuff and minor flow rocks. The Mount Rankin Beds in the north and the upper part of the sequence in the type area are approximate correlates of and are lithologically similar to the Drummond Group including the Telemon Formation.

The Mount Wyatt Beds (Daintree, 1870) were defined in Malone et al. (1966). They form the basal part of the Mount Rankin Beds in the north and contain evidence of a short-lived marine incursion probably from the east or northeast. The field data are insufficient to locate the top and bottom of the unit accurately and consequently it has not been defined formally as a formation.

The small westerly trending outcrop of Mount Rankin Beds 60 km north of Mount Coolon is tentatively included in the Mount Rankin Beds. The sequence consists of dark deeply weathered and altered crystal tuff, with subordinate dark fine-grained flow-banded slightly porphyritic rhyolite and bedded conglomeratic tuff. The rocks are similar in a general way to the volcanics in the lower part of the Mount Rankin Beds, but this outcrop lies to the north of the known limits of the volcanic sequence in the Mount Rankin Beds. The volcanics north of Mount Coolon may belong to the Ukalunda Beds which contain some similar rock types, although they do not generally consist mainly of volcanics. These rocks are structurally discordant with the overlying Bulgonunna Volcanics which contain many similar rock types; the structural discordance may be the result of extrusion from different foci and may not justify excluding these rocks from the Bulgonunna Volcanics.

A small outcrop at the northern margin of the Anakie Inlier has been assigned to the Mount Wyatt Beds on the basis of lithology and flora. The outcrop is separated from the Drummond Basin by the overlying Bulgonunna Volcanics. Possibly, the Drummond Group and Mount Wyatt Beds were continuous around the northern end of the Anakie Inlier. If so, the basal part of the Drummond Group in the north may have been deposited in a marine environment.

Theresa Creek Volcanics

The stratigraphic position of the Theresa Creek Volcanics (Veevers et al., 1964b) is not known with certainty. Veevers et al. stated that they are conformable on unnamed Middle Devonian sediments and regarded them as approximate correlates of the Dunstable Volcanics (then the Dunstable Formation), unnamed Middle Devonian volcanics and sediments, the Silver Hills Volcanics, and the volcanics of the Mount Rankin Beds (see Fig. 8 in Veevers et al., 1964b). Later work has shown that there are two suites of volcanics separated by an unconformity: a Middle Devonian suite of which the Dunstable Volcanics is typical, and an Upper Devonian suite to which the Silver Hills Volcanics and the volcanics of the Mount Rankin Beds belong. The Theresa Creek Volcanics probably contain representatives of both. The lithology of part of the Theresa Creek Volcanics suggests that they can be correlated with the Upper Devonian volcanics. The conformable relationship (Veevers et al., 1964b, p. 10) between the unnamed Middle Devonian sediments and the overlying Theresa Creek Volcanics, and the fact that the Theresa Creek Volcanics are intruded by monzonite which is correlated with the Retreat Granite suggest that part of the Theresa Creek Volcanics is Mcddle Devonian in age. The Retreat Granite was probably emplaced in the interval between the Middle Devonian and Upper Devonian volcanic suites, and is overlain non-conformably by the Upper Devonian Silver Hills Volcanics. The isotopic age of the Retreat Granite suggests that it is probably younger than the Middle Devonian volcanics.

Connors Volcanics

The Connors Volcanics which consist mainly of massive volcanics, are exposed in small areas adjacent to the Urannah Complex and in a large area at the southern end of the Connors Arch, and in inliers nearby. Most of the outcrops lie within the Duaringa and Saint Lawrence Sheet areas (fee Malone et al., 1969). The Connors Volcanics in the Bowen Sheet area are defined and described in Malone et al. (1966), and in the Mackay Sheet area they are referred to in Jensen, Gregory, & Forbes (1966). The Connors Volcanics were not recognized in the Mount Coolon Sheet area when it was mapped in 1960 (Malone et al., 1964) and were included in the Lower Bowen Volcanics, but they are distinguished from the Lizzie Creek Volcanics (= Lower Bowen Volcanics) in a later publication (Malone, 1968).

No intrinsic evidence of age has been found in the Connors Volcanics. Field relationships indicate that they are unconformably overlain by Lower Permian Volcanics and sediments. In the south they are intruded by a granodiorite stock, which has an isotopic mineral age of about 305 m.y. (early Upper Carboniferous). The Connors Volcanics are only in contact with the overlying Permian rocks, with intrusive rocks of various ages, and with the partly Lower Permian Rannes Beds. The isolated blocks of Connors Volcanics have been recognized by lithology only, and they may include rocks of different ages. The Connors Volcanics may be correlated with either the Upper Silurian to Lower Devonian rocks of the Craigilee area or the Devonian-Carboniferous Campwyn Beds; both of which are not lithologically dissimilar. However, the Connors Volcanics are mainly terrestrial, and do not contain fossiliferous marine sediments which are found in both the other two units. Spilitic rocks have been tentatively identified in the Connors Volcanics, particularly in the south, and it is possible therefore that they are partly submarine. It is unlikely that the Connors Volcanics can be correlated with the Upper Carboniferous Bulgonunna Volcanics cropping out northwest of the Bowen Basin. Tenuous deductions based on isotopic age determination suggest that the Bulgonunna Volcanics may be younger than the 300-m.y. old granodiorite which intrudes the Connors Volcanics.

The relationships of the Connors Volcanics with the Rannes Beds and Camboon Andesite are discussed later.

The Connors Volcanics and Urannah Complex together form the Connors Arch which forms part of a major axis of uplift, subsidence, and intrusion along the western margin of the Eungella-Cracow Mobile Belt; the linearity of the axis may be largely the result of post-Permian tectonics. The relationships with the overlying Permian rocks indicate that the blocks of Connors Volcanics resisted deformation during the post-Permian folding, although the blocks were displaced relative to each other. No cleavage has been developed in the Permian sediments to the west of the largest block of Connors Volcanics, whereas there is a well defined axial-plane cleavage in similar sediments to the south and east. The relative movement of the blocks is suggested by the intense shearing of sediments between them. The distribution of the overlying sediments indicates that some of the inliers of Connors Volcanics were partly emergent at the beginning of Lower Permian sedimentation and were progressively overlapped by younger sediments.

Campwyn Beds

The volcanics and sediments of the Campwyn Beds crop out near the coast from 80 km south of Mackay to beyond the northern margin of the map area. In the Mackay Sheet the unit was named and described by Jensen et al. (1966), and the occurrences in the southern part of the Proserpine Sheet area are described in Jensen (1963).

The identification of the Campwyn Beds near Koumala is based on lithology only. The beds are faulted against or intruded by the Urannah Complex with which they form a block overlain unconformably by the Lower Permian Carmila Beds. The blocks of Campwyn Beds along the coast are faulted along their western margins where they are in contact with Lower Permian rocks.

The Campwyn Beds possibly represent the northern extension of the Yarrol Basin sequence. The Upper Devonian and Carboniferous fauna and flora indicate that the Campwyn Beds were laid down at the same time as the Yarrol Basin sequence. The stratigraphy of the Campwyn Beds is not well known, and no attempt has been made to correlate them with the Yarrol Basin sequence. The massive nature of the volcanics, the abundance of plant remains, and the presence of fossiliferous marine interbeds suggest that the Campwyn Beds were deposited near the shore in alternating terrestrial, freshwater, and marine environments, possibly on the northwest margin of the Yarrol Basin. The southernmost outcrop of the Campwyn Beds on West Hill Island is only 50 km from Long Island where the Yarrol Basin sequence has been recognized. The distribution of the two sequences and the similarity in lithology and total thickness suggests that they probably were laid down in the same basin.

The style of folding of the Campwyn Beds is also similar to that of the Yarrol Basin sequence. The entire thickness of the Campwyn Beds was apparently folded into broad structures in which almost the complete sequence can be seen in the preserved limbs of the folds. Tight minor folding has developed in places, generally associated with faulting.

The Campwyn Beds and associated pre-Permian intrusive igneous rocks formed the basement on which part of the Carmila Beds was deposited. Near Koumala, the unconformity at the base of the Carmila Beds is exposed around a structural high of Campwyn Beds and igneous rocks. The Carmila Beds to the south are folded into the southerly plunging Carmila Syncline; to the north, they dip north from the high, but their structural configuration is obscure. The structurally high position of the Campwyn Beds may be partly due to post-Permian folding, and partly due to the presence of a topographic ridge on the pre-Permian basement. The blocks of Campwyn Beds along the coast have been uplifted as a result of post-Permian faulting. The faults have truncated the eastern flank of the Carmila Syncline; about 2100 m of the Lower Permian sequence has been removed and the underlying Campwyn Beds exposed. The apparent relative movement on the faults is east block up, but the nature of the fault system is unknown.

Yarrol Basin Sequence

Only the western edge of the Yarrol Basin sequence is exposed in the map area. Most of the sequence lies within the Port Clinton, Rockhampton, and Monto Sheet areas. Recent reports describing the Yarrol Basin sequence include: Kirkegaard, Shaw, & Murray (1966, and in prep.) (Rockhampton and Port Clinton Sheet area); Dear (1968) (Cania district, Monto Sheet area); and Dear, McKellar, & Tucker (in prep.) (Monto Sheet area).

The Yarrol Basin sequence (D-Ca) has been mapped in a few small areas about 30 km south of Marlborough and in the southern part of Long Island. The faunas collected at various localities and the lithology suggest that most of the Yarrol Basin sequence is represented, but insufficient information was available to subdivide the sequence. The Neerkol Formation (Cu) and Lower Carboniferous sediments (Cl) were mapped on the eastern and western flanks of the Craigilee Anticline and have been tentatively recognized at the northern end of Long Island. Lower Permian sediments occupy most of Quail Island.

Revised mapping (Kirkegaard et al., in prep.) of the Long Island area is presented in Figure 6. It differs from the published 1:500,000 geological map in that Lower Permian sediments are recognized on Quail Island, and includes a more accurate map of the Upper Carboniferous, Lower Carboniferous, and undifferentiated Devonian-Carboniferous sequences.

The distribution and variations in thickness of the Yarrol Basin sequence suggest that the area south of Marlborough was near the western margin of the basin and that parts of the Silurian-Devonian rocks were emergent at times or throughout the whole period of deposition. The Lower Carboniferous sequence is thinnest on the southwest flank of the Craigilee Anticline where they are up to 600 m thick; east of the Craigilee Anticline, their thickness ranges from about 900 m in the south to about 2400 m in the north. The Lower Carboniferous sequence is disconformably overlain by the Neerkol Formation throughout this area, but there is no evidence that the thickness varies because of erosion of the top of the Lower Carboniferous sequence. Apparently, the Lower Carboniferous sediments onlapped from the northeast towards the south and west over an irregular basement of Silurian-Devonian rocks.

A Lower Carboniferous conglomerate containing clasts of coralline limestone occurs near the base of the Yarrol Basin sequence in the Rockhampton Sheet area, east of the northern end of the Craigilee Anticline. The lithology of the clasts, and their contained fauna, suggest that they were derived from Silurian-Devonian limestones such as now crop out at the northern end of the Craigilee Anticline, about 38 km south-southeast of Marlborough.

The Silurian-Devonian rocks along the northwest flank of the Craigilee Anticline and in inliers farther west are overlain by Permian rocks with no intervening Carboniferous sediments. The absence of Carboniferous sediments suggests that this area lay beyond the western limit of the Yarrol Basin.

The oldest Yarrol Basin sediments in this area are represented by the block of sediments (D-Ca) northwest of the Craigilee Anticline. The sequence includes basal volcanics containing an Upper Devonian fauna. No equivalents of this fauna or of the volcanics have been found in the Yarrol Basin sequence in the Craigilee Anticline. Sedimentation in this area probably commenced in a small embayment bordered to the east and south by Silurian-Devonian rocks. Detritus from Silurian-Devonian rocks was carried eastward into the main Yarrol Basin at least during the Lower Carboniferous, until the area was gradually onlapped from the northeast to southwest.

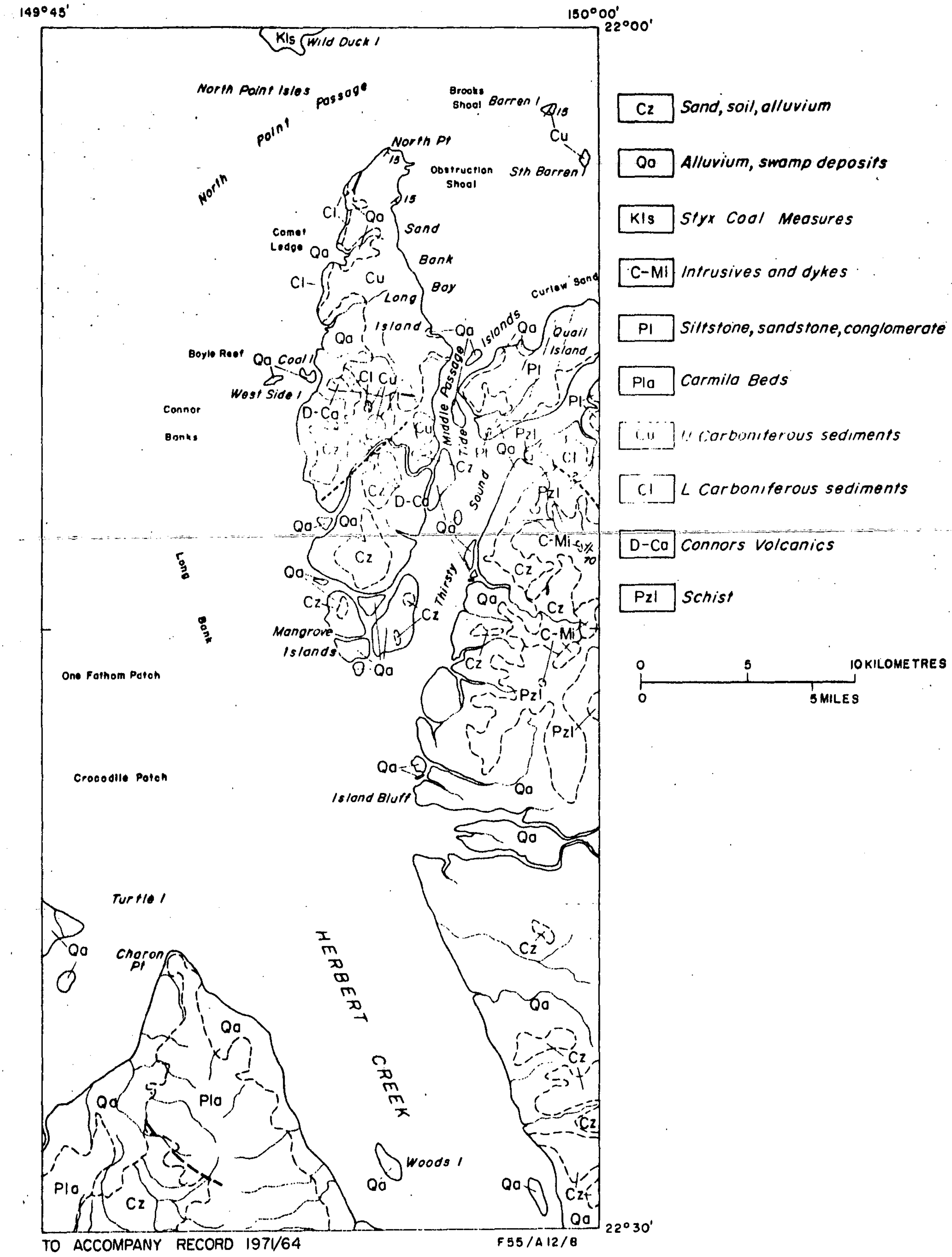
The palaeogeography of this part of the Yarrol Basin is complex, and is not well known.

The sequence on Long Island is not well known. There is apparently no thinning or onlapping of units and the sequence was presumably deposited away from the margin of the basin. The similarity of the rock types, sequence, and faunas to those in the main part of the Yarrol Basin indicate continuity of the depositional area. The separation of these sediments from the rest of the Yarrol Basin is apparently the result of post-depositional folding, faulting, and erosion.

UPPER CARBONIFEROUS TO PERMIAN

In Upper Carbonifeous to Permian times the Bulgonunna Volcanics, Joe Joe Formation, and Torsdale Beds were deposited in widely separated areas around the margins of the Bowen Basin. The Bulgonunna Volcanics are probably the oldest of the three. They consist predominantly of terrestrial volcanic rocks and associated contemporaneous intrusive rocks on the northeast margin of the Clermont Stable Block. They were formed during the last episode of violent tectonism before stabilization of the Clermont Block. The Joe Joe Formation and Torsdale Beds may be largely contemporaneous. The Joe Joe Formation consists of freshwater sediments some of which are of fluvioglacial origin; the Torsdale Beds contain ill sorted conglomerates of possible fluvioglacial origin; both units may have been deposited during the same glacial epoch.

These three rock units are described in Table 3.



TO ACCOMPANY RECORD 1971/64

F55/A12/8

GEOLOGY OF THE LONG ISLAND AREA

Fig. 6

Reduction 1/4

Bulgonunna Volcanics

The Bulgonunna Volcanics (named by Malone et al., 1964; revised by Malone et al., 1966) is a massive wedge of volcanic rocks. The formation thins to the west, where it unconformably overlies the Drummond Group, and disappears to the east under the unconformably overlying Lizzie Creek Volcanics. The southern boundary is obscured by Tertiary sediments. The Bulgonunna Volcanics lie between Lower Carboniferous and Lower Permian rocks. Several samples from Upper Carboniferous plutons intruding the Bulgonunna Volcanics have given concordant isotopic mineral ages of about 285 m.y. which set an upper limit to the age of the volcanics. Two samples from the Devonian-Carboniferous granodiorite near the western margin of the Bulgonunna Volcanics gave anomalous mineral ages of about 290 and 294 m.y. A third sample from the Devonian-Carboniferous granodiorite gave a minimum age of about 330 m.y., and stratigraphic data suggest that the real age may be about 360 m.y. The two samples which yielded anomalous results were probably collected at shallow depth below the surface on which the Bulgonunna Volcanics were extruded, and the low ages may be the result of reheating and recrystallization under the volcanic pile. The age of the Bulgonunna Volcanics and associated igneous intrusions probably ranges from about 295 to 285 m.y., which indicates that they are significantly younger than the Connors Volcanics.

The Bulgonunna Volcanics consist mainly of rhyolite extrusives. The rhyolite flows generally have contorted flow banding which wraps around the quartz, orthoclase, plagioclase, and hornblende phenocrysts. Two other types of porphyritic rhyolite are common: one contains scattered phenocrysts in a dark fine weakly flow-banded glassy or felsitic groundmass; the other, which consists mainly of phenocrysts set in a flow-aligned groundmass, may be a welded ash-flow tuff. The formation includes some dark grey rhyolite porphyry, containing phenocrysts of quartz and feldspar in a fine groundmass of biotite and aphanitic material, which may be the intrusive equivalent of the rhyolites. Possible intrusive rocks were noted in a number of localities, but they generally graded into flow-banded rhyolite of similar composition at their margins. Dacite, toscanite, trachyandesite and rare augite trachyandesite are important constituents of some of the volcanic lenses which constitute the Bulgonunna Volcanics.

Crystal and lapilli tuffs, agglomerate, and volcanic conglomerate make up less than half of the formation. The volcanic conglomerate is possibly a mud-flow conglomerate; it is poorly sorted and contains rounded bombs(?) of porphyritic rhyolite set in a red-brown tuffaceous matrix. Sediments, mainly derived by reworking of tuffs, are a minor constituent of the formation. Near its western margin, the Bulgonunna Volcanics contain a 3-m bed of basal conglomerate which rests unconformably on the Drummond Group; the conglomerate contains rounded pebbles of acid volcanics and quartzite in a hard siliceous matrix.

The Bulgonunna Volcanics consist of a massive wedge composed of an imbricate pile of lenticular basin fills or sheets. The volcanics exhibit depositional dips up to 35° around the margins of the basins. Steeper dips occur on the faulted margins of the basin; the faults are possibly marginal to foundering blocks.

Faulting and jointing are common. In places the joints have a characteristic pattern consisting of an unjointed central boss of porphyritic rhyolite surrounded by porphyritic rhyolite flows with numerous tangential to radial joints.

The apparent absence of a fossil flora from the Bulgonunna Volcanics is surprising. The volcanics contain water-laid sediments, which were probably deposited without much reworking, in which one would expect to find some trace of the vegetation to be preserved. Possibly, the growth of vegetation was inhibited by an extremely cold climate during a glacial epoch which persisted until deposition of the Joe Joe Formation began.

Joe Joe Formation

The Joe Joe Formation, the youngest unit in the Clermont Stable Block, was deposited on a peneplaned surface which truncates the folded Drummond Basin sequence. This surface and the overlying Joe Joe Formation were subsequently tilted gently to the south during subsidence of the Bowen Basin and the succeeding Great Artesian Basin. The base of the Joe Joe Formation is structurally conformable on the Ducabrook Formation in the troughs of synclines, but unconformably overlaps progressively older units on the eroded crests of plunging anticlines. The Joe Joe Formation was bevelled by erosion prior to deposition of the unconformably overlying thin discontinuous sequence of Reids Dome Beds. The Colinlea Sandstone which disconformably succeeded the Reids Dome Beds, rests unconformably on the Joe Joe Formation in many places.

The formation was first described in unpublished reports by geologists of Shell (Qld) Development Pty Ltd (SQD, 1952) and the name was subsequently published by Hill (1957). The main reference to the Joe Joe Formation in the Bowen Basin map area is in Mollan et al. (1969).

Farther west, petroleum exploration wells have penetrated a section of the Joe Joe Formation which includes younger sediments than are present in the type area. Palynological studies (Evans, 1966b) indicate that the formation is mainly Upper Carboniferous, but may range into the Permian.

Torsdale Beds

The Torsdale Beds were first referred to by Dear (Dear & Jensen, 1965) and are defined and described by Dear et al. (in press), who regard it as Upper Carboniferous to Permian in age. Part of the Torsdale Beds, as mapped by Dear et al. are included in the pre-Permian part of the Camboon Andesite in the map area (see discussion below). The Torsdale Beds shown on the map overlie or are faulted against the Camboon Andesite, Auburn Complex, and Back Creek Group. Their relationships are uncertain.

The beds consist of conglomerate, coarse to very fine clastic sediments, some chert, and a variety of acid to intermediate volcanics. The conglomerates are possibly fluvioglacial in origin and the Torsdale Beds may have been deposited during the same glacial epoch as the Joe Joe Formation.

LOWER PERMIAN AND OLDER

The Camboon Andesite and Rannes Beds both contain rocks of known Lower Permian age and both also apparently contain pre-Permian rocks; the Rannes Beds also probably include some Upper Permian sediments.

Camboon Andesite

The name Camboon Andesite was first published by Derrington, Glover, & Morgan (1959) and was referred to by Derrington & Morgan (in Hill & Denmead, eds, 1960, p. 204). As ordinally defined, the unit consists of andesitic volcanics unconformably overlain by the Back Creek Group. The type area described is near Camboon homestead, after which the formation was named. The name was applied to all the volcanics between the Auburn Complex and the Back Creek Group (Laing, in Hill & Denmead, eds, 1960, p. 216) and this usage has been followed on the accompanying geological map, and in reports on the regional mapping of the Bowen Basin. The Camboon Andesite contains a Glossopteris flora near Cracow (Wass, 1965) and a Lower Permian marine fauna in limestone interbeds near Prospect Creek (J.F. Dear, pers. comm.). These fossils establish the Lower Permian age of part of the Camboon Andesite.

A new unit between the Camboon Andesite and the Auburn Complex (the Torsdale Beds) has been delineated on the preliminary edition of the Monto Geological Sheet (1965). The Torsdale Beds, which are described by Dear (Dear & Jensen, 1965) as Upper Carboniferous or early Permian in age, are shown on the geological map of the Bowen Basin in the Prospect Creek area only. The Torsdale Beds shown west of the Auburn Complex on the Monto preliminary edition are thought to be intruded by the complex. Samples from the Auburn Complex have given isotopic mineral and total rock ages of about 311 m.y., which suggests that they are pre-Upper Carboniferous in age and are not equivalent to the Torsdale Beds of the Prospect Creek area. These pre-Upper Carboniferous rocks and the Lower Permian part of the Camboon Andesite are not shown separately on the Bowen Basin map. The precise age of the isolated blocks of Camboon Andesite is also unknown. Thus, the Camboon Andesite, as used in this Bulletin, consists of an upper unit of Lower Permian volcanics and a lower unit of probable pre-Upper Carboniferous volcanics which are intruded by the Auburn Complex.

The Camboon Andesite crops out along the western flank and around the northern end of the Auburn Arch and in isolated fault blocks and anticlinal cores to the north. It is overlapped to the south by the Great Artesian Basin sequence. The formation was mapped in the western part of the Mundubbera Sheet area (Mollan et al., in press), in the Gogango Range area (Olgers, Webb, Smit, & Coxhead, 1964), and in the southeastern part of the Duaringa Sheet area (Malone et al., 1969). Descriptions of the Camboon Andesite and Torsdale Beds, including the older part of the Camboon Andesite in the Monto Sheet area, are contained in a forthcoming publication (Dear et al., in press). The distribution and tentative subdivision of the Camboon Andesite is presented in Plate 1.

Gogango Range Area

The Gogango Range area includes adjacent corners of the Duaringa, Rockhampton, Baralaba, and Monto Sheet areas and extends north-northwest from 8 km south of Rannes to the Fitzroy River. The Camboon Andesite crops out in a series of elongate blocks, which are partly bounded by faults, or in the cores of anticlines. About two-thirds of the formation consists of flow rocks with minor intrusions; the remainder consists partly of pyroclastics and partly of sediments derived from volcanic rocks. Almost all the rocks show the effects of diagenetic or hydrothermal alteration, and are sheared, foliated, and recrystallized to varying degrees as a result of dynamic metamorphism.

Most of the intermediate to basic volcanics are so altered and deformed that it is difficult to distinguish flows, intrusions, and pyroclastics. About 100 thin sections from this area were examined*.

* All the thin sections were examined by Miss B.R. Houston of the Geological Survey of Queensland. Her descriptions are contained in unpublished records (Malone, Mollan, Olgers, Jensen, Gregory, Kirkegaard, & Forbes, 1963, appendix 6; Olgers et al., 1964, appendix 6).

Most of the rocks are so altered that it is difficult to identify the original minerals present, but the descriptions provide a reliable guide as to the main rock types present.

Most of the lavas range from andesite to basalt, but a few trachyte and rhyolite flows are present. The andesites are light greenish grey to dark or purplish grey, fine to medium-grained, commonly altered, sheared, and foliated. They consist of feldspar (usually andesine), clinopyroxene, chlorite, sericite, clinozoisite, epidote, quartz, and siderite. The textures are crudely fluidal, intersertal, subophitic, or rarely hypidiomorphic-granular. Some contain phenocrysts of feldspar and clinopyroxene or their alteration products. Some flows contain amygdales of epidote, chlorite, calcite, quartz, and penninite, and a few contain xenocrysts of quartz; the amygdales are elongated and aligned by shearing in some flows. Most of the feldspars are sericitized or replaced by quartz, chlorite, epidote, and clinozoisite; the clinopyroxenes are largely replaced by actinolite, clinozoisite, chlorite, and epidote.

The basalt flows are as numerous as the andesites. They vary widely in the degree of alteration and shearing, and in composition. Some are nearly identical in texture and composition with the more basic andesite flows. Albite is prêsent in some flows and is the dominant feldspar in one, associated with calcite. In general, the basalt flows are very fine to medium-grained, grey to dark greenish or purplish grey, and are slightly to extensively sheared and foliated. The textures are subophitic, intersertal, or intergranular. They consist mainly of andesine or labradorite, with some oligoclase and albite, pyroxene, clinopyroxene, and olivine. The secondary minerals include sericite, chlorite, epidote, serpentine, hydro-grossularite, clinozoisite, and penninite. Some flows contain phenocrysts of altered feldspar, clinopyroxene, epidote pseudomorphs after pyroxene, serpentine pseudomorphs after olivine(?), and chlorite pseudomorphs. Some flows contain amygdales of quartz, chlorite, epidote, and calcite.

One flow contains about 35 percent albite, 40 percent chlorite, 10 percent calcite, minor hydrogrossularite, and about 15 percent calcite and chlorite amygdales. It is possibly a spilite. The feldspars in other basalt flows are partly albitized, possibly during hydrothermal alteration or as a result of incipient spilitization.

High-level intrusions are moderately common in the volcanic pile. Most of them consist of grey-green fine-grained slightly to extensively altered and sheared diorite, composed of oligoclase-andesite (saussuritized and partly replaced by alkali feldspar), uralitized pyroxene or clinopyroxene, and chloritized tremolite. Some of the basalts may be high-level intrusions also.

All the flows and high-level intrusions are possibly co-magmatic as they are generally similar in mineralogical composition, and in the type and degree of alteration. The Camboon Andesite in this area contains a little sheared and altered trachyte which could be related to the andesite-basalt extrusives and rare porphyritic rhyolite.

Pyroclastic rocks and sediments constitute about one-third of the Camboon Andesite in the Gogango Range area. The pyroclastics consist mainly of lithic, crystal, and vitric tuff, ash-flow tuff, and agglomerate. The pyroclastic rocks are sheared and hydrothermally altered, and in places the groundmass has been recrystallized. Most of the clasts in the pyroclastic rocks are similar to the andesite and basalt lavas.

The finer-grained sediments have been sheared and recrystallized to slate, phyllite, and mica schist and less commonly silicified to cherty mudstone. The coarser sediments include pebbly volcanolithic arenite. The clasts in the arenites were probably formed by reworking of unconsolidated volcanic detritus. Graded bedding in interbedded volcanolithic greywacke and mudstone and the immaturity of the clasts suggest deposition from a turbid volcanic mud flow with little reworking. Some of the arenites have a calcite cement. At one place the formation contains foliated and slightly recrystallized calcirudite. The similarity of the calcirudite to those in the adjacent Rannes Beds suggests interfingering of the Camboon Andesite and Rannes Beds.

In places, the Camboon Andesite includes pahoehoe lava with ropy structures on the flow surfaces and lava rolls; it is closely associated with agglomerate, volcanic breccia, and tuff. The presence of pahoehoe lava indicates subaerial extrusion, but elsewhere, the flows interbedded with well bedded tuff and mudstone were probably laid down under water. The possible presence of spilite and spilitized flows suggests diagenetic adjustment to a hydrous environment, and the presence of crinoidal limestone in the Rannes Beds indicates a marine environment. Thus, the Camboon Andesite in the Gogango Range area was apparently deposited in a partly subaerial, partly marine environment. The Camboon Andesite in the Gongango Range area appears to consist of one unit only, possibly the Lower Permian part.

The Camboon Andesite is overlain by or is locally contemporaneous with the Rannes Beds. The contacts are generally gradational and the interfingering of the Camboon Andesite with the Rannes Beds indicates that they are locally contemporaneous. The common occurrence of Camboon Andesite in the cores of anticlines surrounded by Rannes Beds, however, indicates that most of the Camboon Andesite is older than the Rannes Beds.

Monto Sheet Area

The Lower Permian part of the Camboon Andesite in the southwest corner of the Monto Sheet area is similar in lithology to the sequence in the Gogango Range. In general, it lacks the shearing and intense hydrothermal alteration noted in the Gogango Range, but this probably reflects the lack of structural deformation on the western flank of the Auburn Arch. The rocks in the tightly folded Prospect Creek area are more altered.

In the Prospect Creek area the Camboon Andesite includes beds of limestone containing early Lower Permian fossils. Species of the Glossopteris flora occur in sediments within the volcanics west of the Auburn Arch. In the west, the Camboon Andesite contains beds of conglomerate near the base. The boulders of granite in the conglomerate were presumably derived from the Auburn Complex.

The pre-Permian part of the Camboon Andesite is thought to be intruded by the Auburn Complex. The sequence consists mainly of acid to intermediate volcanics similar to the bulk of the Camboon Andesite in the Mundubbera Sheet area.

Mundubbera Sheet Area

The Camboon Andesite in the Mundubbera Sheet area is described in Mollan et al. (in press). It occupies a narrow longitudinal strip between the Auburn Complex to the east and the overlying Back Creek Group to the west. It is overlapped by the Great Artesian Basin sequence to the south and extends northwards into the Monto Sheet area where it has been divided into two parts (see Pl. 1).

The formation consists of lava flows, some pyroclastics, and a small proportion of sediments, mainly conglomerate. The lava flows consist mainly of andesite and dacite, with subordinate rhyolite and rare trachyandesite. Hornblende is the only mafic mineral in the flows. The feldspars are usually sericitized or saussuritized and alteration of feldspar and hornblende to chlorite, epidote, and calcite is common. However, the degree of hydrothermal alteration is less intense than in the Gogango Range area.

The pyroclastic rocks include crystal, lapilli, lithic, and vitric tuffs and agglomerate; they appear to be mainly andesitic to dacitic in composition. Conglomerate beds, up to 24 m thick, occur in places, possibly in the Lower Permian part of the unit. They contain rounded cobbles of andesite, dacite, and granite: the andesite and dacite clasts were probably derived from the underlying pre-Permian volcanics, and the granite clasts were presumably derived from the Auburn Complex.

Similar conglomerate beds occur at the base of the Lower Permian part of the Camboon Andesite in the Monto Sheet area to the north (J.F. Dear, pers. comm.).

The Camboon Andesite is intruded by a few small stocks of microdiorite, and by dykes of quartz basalt, andesite, and aplite.

The Camboon Andesite in the Mundubbera Sheet area consists mainly of intermediate to acid volcanics and associated sediments, but regional considerations indicate that the formation includes both the Lower Permian and pre-Permian parts. Since most rocks are unlike the Camboon Andesite in the Gogango Range area, most of the formation in the Mundubbera Sheet area is probably pre-Upper Carboniferous, overlain by a relatively thin Lower Permian volcanic sequence. The relationship of the older unit with the Auburn Complex is uncertain, but is probably intrusive. The volcanics near the contact are extensively veined with quartz and are generally hydrothermally altered; the contact itself is locally irregular.

Rannes Beds

The Rannes Beds crop out in an elongate dogleg belt which extends from near Goovigen in the Monto Sheet area to west of Marlborough in the Saint Lawrence Sheet area. The beds have also been tentatively identified in an isolated block south of Biloela. The Rannes Beds in the Gogango Range area of the Duaringa, Rockhampton, Baralaba, and Monto Sheet areas were mapped in considerable detail in 1963; the results of this work and many petrographic descriptions by Miss B.R. Houston of the Geological Survey of Queensland are contained in an unpublished report (Olgers et al., 1964). The entire Rannes Beds are described in Malone et al. (1969) which incorporates much of the unpublished data.

The Rannes Beds consist predominantly of mudstone and arenite, but locally the sequence contains significant proportions of volcanics, conglomerate, and calcareous sediments. The mudstone and arenite occur as thick to thin-bedded homogeneous units, or are thinly to thickly interbedded with one another or with the other rock types. The entire sequence has undergone low-grade regional metamorphism and low-grade to locally moderate dynamic metamorphism. The argillaceous sediments have been converted to foliated mudstone, slate, phyllite, mica schist, and sericite schist. In the arenites the matrix has been slightly or largely recrystallized, and the rocks are foliated or fracture-cleaved. Where mudstone and arenite are interbedded, the mudstone is closely foliated and the arenite is cut by widely spaced joints and fracture cleavage planes.

Shearing, foliation, and recrystallization of the fine lithic and crystal tuffs and tuffaceous sediments is common. The chlorite schist cropping out in one place was apparently formed by intense shearing of a very fine crystal-lithic tuff. The lavas and agglomerate are generally sheared and silicified, but show few affects of recrystallization. The basalt in the Gogango Range area is extremely altered and sheared and closely resembles similar rocks in the underlying Camboon Andesite. Silicification, shearing, incipient recrystallization of the matrix, and elongation and alignment of pebbles is common in the volcanic and quartz-lithic conglomerates.

Calcareous sediments are common in the Rannes Beds only in the southern part of the Gogango Range. They include pinkish grey sheared and recrystallized crinoidal calcarenite; foliated fine-grained partly recrystallized pebbly limestone, containing flattened and aligned pebbles of volcanic rocks; and fossiliferous pink and grey limestone, partly recrystallized to marble, interbedded with volcanics and tuffaceous sediments.

The Rannes Beds crop out in a structural zone referred to as the Gogango Overfolded Zone. The beds generally dip at between 40° and 70° to the east and are apparently tightly folded and overfolded. Recumbent folds are exposed in road cuttings in the Gogango Range west of Grantleigh siding; all flanks of these folds dip to the east at less than 40° and the axial planes dip at 15° to the north-northeast. The Rannes Beds cropping out in a road cutting 6½ km west of Grantleigh homestead are folded into small folds with flank dips of about 30° and vertical axial planes; these beds are cut by many normal faults and are less closely foliated than most of the Rannes Beds. In many areas, the bedding in the Rannes Beds is obscured by shearing.

The foliation in the Rannes Beds generally dips steeply east and generally cuts the bedding at angles of up to 45°. It does not appear to bear a constant relationship to the folds in the Rannes Beds. Possibly, the Rannes Beds were folded first and then foliated during a subsequent period of deformation which also modified the existing folds. Two directions of foliation were noted in a few outcrops. Small normal and thrust faults are common; the easterly dip of the thrust faults indicates compression from the east. Joints and quartz veins are common, particularly adjacent to lineaments which can be readily identified on the air-photographs; the lineaments probably represent fault zones.

The Rannes Beds overlie and interfinger with the Camboon Andesite in the south and mainly overlie the Connors Volcanics in the north; in one area, the Rannes Beds appear to underlie an east-dipping wedge of Connors Volcanics, but the contact is concealed and the relationship may be the result of faulting. The Rannes Beds are overlain by the Rookwood Volcanics to the east and are unconformably overlain by the Upper Permian Boomer Formation. The unconformity is exposed 60 km north of Duaringa where the Boomer Formation dips at 10° to the west off the underlying Rannes Beds which dip at about 70° to the east. The relationship of the Rannes Beds to the Lower Permian basal part of the Back Creek Group is obscure. Rare fossils indicate that the basal part of the Back Creek Group has been included with the Rannes Beds in a few places, but they are probably of limited extent and are possibly faulted against the Rannes Beds. The basal part of the Back Creek Group is separated from the overlying Boomer Formation or its equivalents by a disconformity, or by a slight angular unconformity where the middle part of the Back Creek Group is missing. Where the group is complete, the Back Creek Group is conformable with the overlying Boomer Formation. Where there is a marked angular unconformity separating the Rannes Beds from the Boomer Formation, the Rannes Beds presumably include sediments of pre-Permian age which are possibly the same age as the Connors Volcanics. However, most of the Rannes Beds in the Gogango Range are probably the same age as the Lower Permian part of the Camboon Andesite. In the north, the Rannes Beds include some of the lower part of the Back Creek Group and possibly some of the Carmila Beds.

The younger sediments included in the Rannes Beds belong mainly to the Boomer Formation from which they are difficult to separate. The Boomer Formation includes lithic arenite and mudstone similar to those in the Rannes Beds, all of which in the Gogango Overfolded Zone have been folded, cleaved, and faulted. The abundance of faults in this zone precludes generalization over large areas.

Petrographic examination suggests that the Rannes Beds have undergone significantly more metamorphism than the Boomer Formation. Recrystallization of argillaceous material is much farther advanced in the Rannes Beds, and the arenites in the Boomer Formation are indurated rather than metamorphosed as they are in the Rannes Beds. It may be possible to separate the Rannes Beds from the Boomer Formation by detailed mapping, and petrographic studies. Mapping of the pre-Permian part of the Rannes Beds, where they are markedly unconformable under the Boomer Formation, may be more difficult.

The block of Rannes Beds south of Biloela is lithologically similar to but more sheared than the Upper Permian Blenheim Subgroup sediments (shown on the 1:500,000 geological map as Back Creek Group, undifferentiated) from which it is separated by a fault. It may be of Upper Permian age, but has undergone more structural deformation than the Blenheim Subgroup.

It is possible that the Rannes Beds in the Gogango Range and farther north contain equivalents of the Boomer Formation which are regarded as Rannes Beds because they have been more highly deformed than the bulk of the Boomer Formation. Such a situation may exist east of Duaringa where the structures appear to cut across the boundary between the Rannes Beds and Boomer Formation, and where the Boomer Formation appears to underlie Rannes Beds though the boundary is faulted. The distinction between the Rannes Beds and Boomer Formation is based on the difference in the degree of structural deformation and differences in gross lithology. The Rannes Beds are mainly lutites and are isoclinally folded and overfolded; the Boomer Formation consists of interbedded arenites and lutites folded into relatively broad asymmetrical folds. The structural differences may be due to differences in lithology: the lutites could have been shear-folded into an isoclinal pile; while the interbedded arenites/lutites were folded by flexural-slip folding into more open folds. Alternatively, the lutite sequence may belong to the Lower Permian Rannes Beds and the structures may have been developed partly during an earlier period of deformation and partly during the more important Upper Permian orogeny. If these Rannes Beds are Lower Permian, detailed structural studies may reveal the existence of a subfabric not present in the Boomer Formation; complete similarity of fabrics in the two units would suggest their time equivalence but would not be conclusive.

The data available at present are inadequate to determine the age and relationships of all the rocks mapped as Rannes Beds.

Conclusions

Three predominantly volcanic units can be recognized around the Auburn Arch: the pre-Upper Carboniferous acid to intermediate volcanics, intruded by the Auburn Complex and mapped as Camboon Andesite on the 1:500,000 geological map, but tentatively distinguished separately on Plate 1; the Upper Carboniferous to Lower Permian Torsdale Beds in the Prospect Creek area; and the intermediate to basic volcanics belonging to the Lower Permian part of the Camboon Andesite.

The Rannes Beds are partly lateral equivalents of and partly younger than the Lower Permian part of the Camboon Andesite and are largely of Lower Permian age. North of Duaringa, they include rocks which are unconformable beneath the Boomer Formation and which are possibly about the same age as the Connors Volcanics. Elsewhere, the Rannes Beds probably include equivalents of the basal part of the Back Creek Group, the top part of the Carmila Beds and, perhaps most commonly, of the Boomer Formation.

There is at least one other possibility. The Camboon Andesite and associated Rannes Beds of the Gogango Range area may not be of the same age as the fossiliferous Lower Permian Camboon Andesite on the flanks of the Auburn Arch. The Gogango Range units may be pre-Permian and are possibly of the same age as the Rannes Beds and associated Connors Volcanics which are unconformable beneath the Boomer Formation farther north. The pre-Permian age is supported by the size of the crinoid stem ossicles in the limestones in the Rannes Beds; the ossicles are generally about 3 mm in diameter which is very much smaller than the ossicles found in the fossiliferous Permian rocks. No diagnostic fossil faunas have been found in the Gogango Range area. A small coral fauna has been collected near Thuriba homestead, 19 km northwest of Rannes. The corals have been recrystallized and the internal structure partly destroyed. However, they are similar in shape and size to the corals in the Silurian-Devonian faunas of the Craigilee Anticline to the north and are dissimilar to the corals in the Permian rocks of the Gogango Range area. This is a possible indication of pre-Permian age which cannot be ignored in the absence of positive proof of a Permian age for the Camboon Andesite and Rannes Beds in the Gogango Range.

Even if the Rannes Beds in the Gogango Range area are pre-Permian, this does not affect the probability that the Rannes Beds, as mapped, include some Lower Permian and Upper Permian sediments.

PERMIAN-TRIASSIC STRATIGRAPHY OF THE BOWEN BASIN

The Permian-Triassic sequence was first mapped in the Bowen River area (Jack, 1879a, b). The basin is only part of the original depositional area. It has a structurally deformed eastern margin which bears little resemblance to the eastern boundary of the depositional basin, and a mildly deformed western margin which approximately coincides with the boundary of the depositional basin. To the south the Bowen Basin is concealed beneath the Jurassic-Cretaceous sequence of the Great Artesian Basin.

Deposition in the Bowen Basin began in four areas in the early Lower Permian, when the Reids Dome Beds were laid down in the Denison Trough, the Camboon Andesite in the Auburn Arch area, and the laterally equivalent and locally continuous Lizzie Creek Volcanics and Carmila Beds in the northern part of the basin. These sequences were laid down in separate areas of downwarping within the basin. Later, in the Lower Permian, sedimentation was more widespread, and from then onwards the sequence laid down was generally continuous throughout the basin. The rock units of basin-wide extent comprise the Back Creek Group and its three subgroups, the Tiverton, Gebbie, and Blenheim Subgroups; the Blackwater Group; and the three formations of the Mimosa Group, the Rewan Formation, Clematis Sandstone, and Moolayember Formation. The thickness and lithology of these units varied from area to area and the loci of maximum sedimentation of successive units shifted from place to place through time. The term 'basin-wide extent' indicates that each of the units was deposited over the entire depositional area existing at that time.

As a result of structural deformation, the Bowen Basin sequence is well displayed in several separate areas of outcrop which are mostly connected subsurface. Interpretation of the Permian-Triassic stratigraphy of the whole basin is based on identification of the rock units of basin-wide extent in these various areas. The Back Creek Group and its subgroups and the Blackwater Group consist of different formations in different areas. The basin-wide units can be identified by their gross lithology, stratigraphic sequence, and the type of lithological changes at unit boundaries, and they can be correlated from area to area by their outcrop and subsurface distribution and by palaeontological data. The Mimosa Group is represented by the same three formations everywhere (see Fig. 7).

EARLY LOWER PERMIAN

The Camboon Andesite and Rannes Beds have been discussed above. The Reids Dome Beds, Lizzie Creek Volcanics, and Carmila Beds are briefly described in Table 4. The distribution and thickness of the four early Lower Permian rock units are shown in Figure 8; the isopachs and estimated thicknesses are based on outcrop data and a limited amount of subsurface data.

The distribution of the Camboon Andesite shown on Figure 8 refers only to the known Permian part of the unit as shown on the geological map of the Bowen Basin. The western limit of the Camboon Andesite is mainly hypothetical except near the Burunga well.

Reids Dome Beds

The Reids Dome Beds crop out in the core of the Springsure Anticline where the exposed sequence was named the Orion Formation in an unpublished report by Patterson (1955). The only other outcrop is the thin sequence between the Joe Joe Formation and Colinlea Sandstone 109 km west of Springsure. The Reids Dome Beds are best known in petroleum exploration wells. A maximum thickness of 9057 feet (2760.5 m) was penetrated in AAO Westgrove 3 though this well did not reach the bottom of the unit. The thicknesses penetrated in various wells are listed in Table 5.

The Reids Dome Beds are named and described in Mollan et al. (1969). They consist essentially of: (1) A basal unit of black shale and mudstone with coal seams and anhydrite layers and interbeds of hard carbonaceous anhydritic sandstone and orthoquartzite; the basal unit contains elements of the Glossopteris flora and is probably Permian in age. (2) A middle unit of black to grey carbonaceous micaceous shale, siltstone, and sandstone with minor coal and thin dolomite beds and local thick beds of polymictic conglomerate, particularly in the south; the thick sequence of interbedded volcanolithic pebble conglomerate and lithic feldspathic sandstone (volcanolithic?) at the base of AFO Rolleston 1 possibly belongs to this middle unit. (3) An upper unit of interbedded fine to coarse carbonaceous sandstone, dark carbonaceous siltstone and shale, and coal. The upper unit includes the Orion Formation.

The abundant Glossopteris flora in the middle and upper units indicates a Permian age. The stratigraphic position of the Reids Dome Beds indicates that they are no younger than early Lower Permian. Rare marine fossils were noted in the sequence in AAO Kildare 1, but the depositional environment was dominantly non-marine.

The stratigraphic relationships on the Springsure Anticline and in some of the well sections indicate that the Tiverton Subgroup transitionally succeeded the Reids Dome Beds in places. Relationships in other wells and the presence of conglomerate in the Tiverton Subgroup suggest that it is disconformable on the Reids Dome Beds elsewhere.

The possible distribution of the Reids Dome Beds is shown in Figure 8. The occurrence of andesite at the base of the Morella 1 well poses some problems. The occurrence of andesite pebbles in the basal beds of the overlying Tiverton Subgroup suggests that the andesite is older than the Tiverton Subgroup. If the andesite is also older than the Reids Dome Beds, then it was part of an irregular basement ridge projecting into the depositional area of the Reids Dome Beds. Alternatively, the andesite represents local vulcanism during deposition of the Reids Dome Beds. The occurrence of volcanolithic(?) sandstone and volcanolithic pebble conglomerate in the Reids Dome Beds in the Rolleston 1 and AAO 7 (Arcadia) wells lends some support to this interpretation.

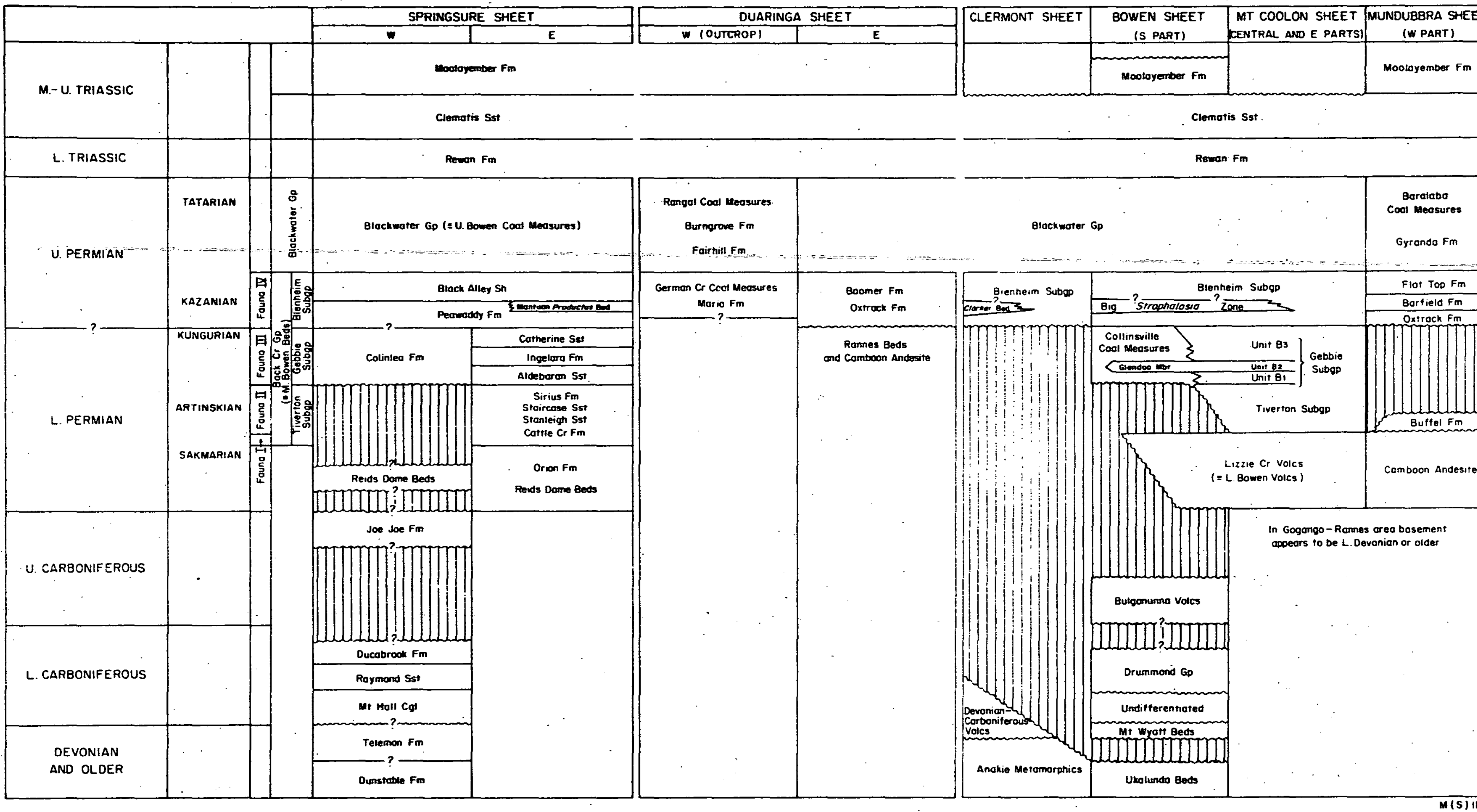


Fig 7 CORRELATION OF PERMIAN FORMATIONS TO ACCOMPANY RECORD 1971/64

In previous interpretations (e.g. Malone, 1964) the andesitic volcanics in the AAO 7 (Arcadia), Morella 1, and Glenhaughton 1 wells were correlated with the Camboon Andesite. The present interpretation, illustrated in Figure 8, suggests that the Reids Dome Beds are separated from the Camboon Andesite by a ridge of pre-Permian rocks. This is supported by the presence of plant-bearing metasediments below the Tiverton Subgroup in Purbrook 1. The rocks below the Tiverton Subgroup in other wells beyond the eastern extent of the Reids Dome Beds contain no palaeontological evidence of age. In Cabawin 1, 163 km south of the map area, the Tiverton Subgroup unconformably overlies probable pre-Permian volcanics of which the upper 60 m are deeply weathered. About 19 km farther south, the volcanic basement rocks beneath the Moonie oil field have been isotopically dated as Carboniferous or older. These meagre data refer to a very large area but they tend to support the hypothesis of a pre-Permian ridge between the Reids Dome Beds and the Camboon Andesite rather than to contradict it. So too does the following interpretation of the sequence at the base of Burunga 1. The volcanics at the base of this well consist of 54 m of white to green welded tuff and andesite flows overlying weathered calcitic hematitic andesite flows. The present interpretation is that the upper 54 m of volcanics represent the thin western edge of the Permian Camboon Andesite unconformably overlying pre-Permian volcanics. On this hypothesis, the volcanics beneath the Tiverton Subgroup in Glenhaughton 1 are pre-Permian in age and were either beyond the limit of deposition of the Reids Dome Beds or were exposed by erosion before deposition of the Tiverton Subgroup.

The ridge postulated as separating the depositional areas of the Reids Dome Beds and the Camboon Andesite may have been a positive topographic feature during the Lower Permian, but it has since been deeply depressed beneath the Mimosa Syncline.

Carmila Beds and Lizzie Creek Volcanics

The Carmila Beds in the Mackay Sheet area were named and described in Jensen et al. (1966). Their distribution in the southern half of the Proserpine Sheet area is described in Jensen (1963), and a more detailed description of other outcrops in the map area is given in Malone et al. (1969).

The Lizzie Creek Volcanics (previously the Lower Bowen Volcanics) were named in Malone et al. (1969). His report contains a resume of the distribution and a full description of the formation in the Saint Lawrence Sheet area. The formation has been described as part of the Lower Bowen Volcanics in the Mount Coolon Sheet area by Malone et al. (1964), in the southern half of the Bowen Sheet area by Malone et al. (1966), in the Mackay Sheet area by Jensen et al. (1966), and in the southern half of the Proserpine Sheet area by Jensen (1963).

The distribution and some of the relationships of the Carmila Beds and Lizzie Creek Volcanics are illustrated in Figure 8. In the northeast the Carmila Beds are bounded by uplifted pre-Permian rocks, but the area of deposition probably extended farther northeast. The western boundary of the two units is largely hypothetical, except in the north where the Lizzie Creek Volcanics wedge out rapidly to the west against a basement of Upper Carboniferous volcanics and intrusives. The conglomerates near the base of the Lizzie Creek Volcanics were deposited not far from their source, and it can be inferred that the westernmost outcrops of the volcanics probably lie near the shore of the original depositional basin. The exposed plan width of the Lizzie Creek Volcanics in the north, from the maximum thickness adjacent to the Urannah Complex to the western limit of outcrop, was used to locate the postulated western subsurface limit of the two units.

The areas of Urannah Complex and Connors Volcanics shown in Figure 8, flanked by the Carmila Beds and Lizzie Creek Volcanics, have been exposed as a result of post-Lower Permian tectonics which produced the Connors Arch (Pl. 3). Both Lower Permian units contain some probable terrestrial volcanics, but both contain near the top, fossiliferous marine sediments which crop out east and west of the Connors Arch as well as in a few places on the arch. Thus, the entire depositional area had subsided beneath the sea by the end of the early Lower Permian. The area has since been uplifted. The thickness of the early Lower Permian units on the Connors Arch is uncertain, but was apparently considerably less than to the east or west. The crest of the Connors Arch was possibly an area of moderate subsidence flanked to the west and east by deep narrow troughs.

The gross lithology of the Lizzie Creek Volcanics is distinctly different from that of the Carmila Beds. In general they occupy separate areas, the Lizzie Creek Volcanics to the west of the Connors Arch and the Carmila Beds to the east and south. The contact on the Connors Arch is placed between acid crystal tuff of the Carmila Beds on top and andesite agglomerate and tuff of the Lizzie Creek Volcanics. The Camila Beds and Lizzie Creek Volcanics probably interfinger on the Connors Arch. The andesitic volcanics and associated sediments of the Lizzie Creek Volcanics were deposited in the trough to the west of the Connors Arch at about the same time as the acid volcanics and sediments of the Camila Beds were laid down in the trough to the east. The sequence on the Connors Arch, which was probably deposited mainly late in the early Lower Permian, is a mixture of both types. The Lizzie Creek Volcanics near Hazelwood Creek contain thick sills of microdiorite. The sills are located along the locus of maximum thickness of the formation, and possibly many of the vents from which the Lizzie Creek Volcanics were erupted were located along this line,

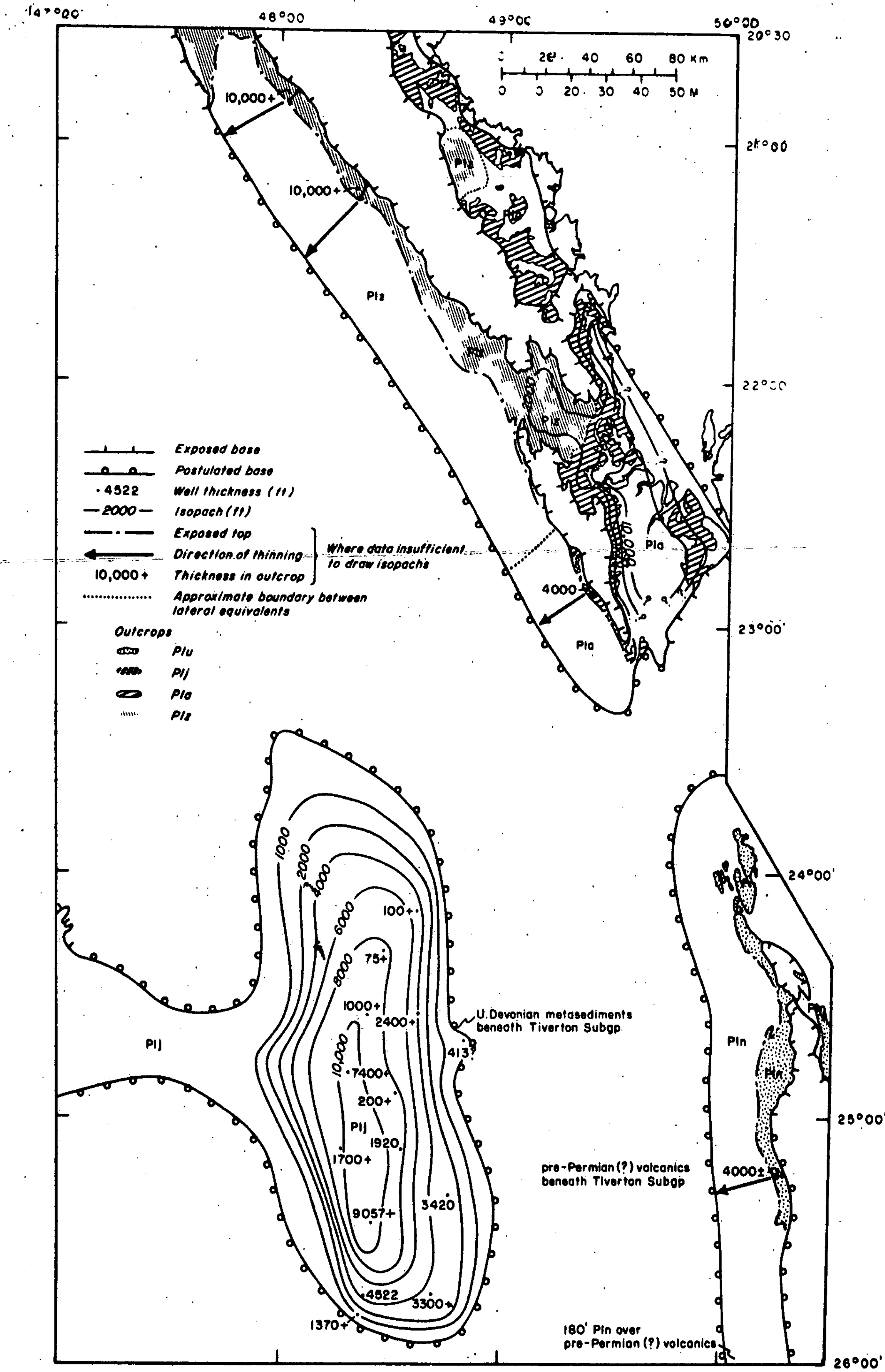


Fig. 8

G/A 347

To accompany report 1971/64

Outcrops of the Camboon Andesite (Pln), Reids Dome Beds (Plj) Carmila Beds (Pla), and Lizzie Creek Volcanics (Plz) that is, along the line of maximum downwarping and crustal tension west of the Connors Arch. The vents supplying the Carmila Beds were possibly located in a similar position on the eastern flank of the arch. The crest of the Connors Arch subsided below the sea late in the early Lower Permian. The subsidence and transgression of the sea coincided with the cessation of vulcanism over much of the area. Subsidence of the Connors Arch reduced the crustal tension beneath the adjacent deeply downwarped linear troughs, and may have had a causative relationship to the cessation of vulcanism.

The westernmost outcrops of Lizzie Creek Volcanics consist mainly of basaltic volcanics, and their tectonic setting is also different from the main outcrops. Here the formation consists of a relatively thin only slightly folded sequence of interbedded volcanics and sediments which were laid down on a slowly subsiding stable block rather than in a narrow trough. The sediments were mainly derived from the west.

The southern boundary of the Carmila Beds on Figure 8 is partly conjectural. In part, it is faulted against a block of serpentinite and Lower(?) Palaeozoic metamorphics which were probably uplifted in the late Lower Permian. Farther southwest, the extent of the Carmila Beds is obscured by overlying units, but it appears to be wedging out to the southeast either as a result of non-deposition or of erosion following uplift in the late Lower Permian. The Carmila Beds are not present between the Boomer Formation and underlying pre-Permian rocks, and the distribution of the Tiverton and Gebbie Subgroups indicates that a large area in the southeast part of the map area was one of non-deposition and erosion during the late Lower Permian.

Relationships and Tectonics

In various places marine fossils appear near the top of all four early Lower Permian units or they pass upwards into sediments containing marine fossils. All these faunas are of approximately the same age and indicate that deposition ceased about the same time. Deposition of the four units may not have commenced at the same time, but they must be largely contemporaneous.

Figure 8 reveals that the early Lower Permian units are preserved in three areas which have different tectonic histories. The Reids Dome Beds were deposited in the northerly trending elongate Denison Trough which was later uplifted along a few long north-trending anticlinal axes. The thin veneer of Reids Dome Beds west of the Denison Trough were laid down on a slowly subsiding shelf. In the south and east, abundance of conglomerate in the Reids Dome Beds suggests that there was considerable topographic relief along the shores of the trough.

Most of the Lizzie Creek Volcanics and Carmila Beds were deposited in long narrow troughs separated by a geanticline which provided a source of detritus for both troughs. Later the geanticline subsided beneath the sea, and finally became the locus of great uplift. The northeastern margin of the depositional basin is unknown. To the south and west, it was flanked by a slowly subsiding stable shelf on which a thin cover of sediments was laid down.

The Lower Permian Camboon Andesite consists mainly of andesite and rhyolite with only minor sediments. It was possibly deposited as a single elongate body, which was later cut into two parts by erosion after the uplift of the Auburn Arch. Most of the formation was possibly laid down in a terrestrial environment, but fossiliferous marine limestone occurs near the top of the formation in the east. In the west the marine transgression came somewhat later as the overlying marine sediments are disconformable on the Camboon Andesite. The Camboon Andesite wedged out to the west against the postulated ridge which separated its depositional area from that of the Reids Dome Beds. The relationship of the Camboon Andesite to the rocks to the north is obscure. They possibly wedge out against or were eroded off a block of Rannes Beds and the pre-Permian(?) part of the Camboon Andesite. An alternative explanation assumes that the Rannes Beds and both parts of the Camboon Andesite are of Lower Permian age and that the Camboon Andesite is replaced to the north by contemporaneous rock units of very different lithology. The solution of this problem is essential to an understanding of the tectonics in this area.

The abundance of conglomerate in the Reids Dome Beds indicates the presence of elevated land to the east and south of the Denison Trough, but the relief was probably greatly reduced before the fine clastics and coal of the upper part of the Reids Dome Beds were deposited. Apparently, the land areas between the early Lower Permian depositional basins were gradually eroded and perhaps peneplaned prior to the end of the early Lower Permian when the sea transgressed the entire area. The distribution of the overlying units indicates, however, that the rate of subsidence varied from place to place.

BACK CREEK GROUP

The stratigraphical unit now known as the Back Creek Group was first recognized by Jack (1879a,b; Jack & Etheridge, 1892), who applied the name Middle Bowen Beds to the predominantly marine sediments of the Bowen Basin. Subsequent work has confirmed that the unit is stratigraphically well defined and of considerable extent in both space and time. It can be subdivided into small recognizable units, and contains no major unconformities. It was therefore referred to as the Middle Bowen Group in some publications - notably the Geological Map of Queensland (Hill, ed., 1953). The formal name Back Creek Group was first used by Derrington et al. (1959) and Derrington & Morgan (in Hill & Denmead, eds, 1960, pp. 204-7) for the succession in the Theodore-Cracow area, and is now applied throughout the basin.

In the northern part of the basin, Malone et al. (1966) divided the group into the Tiverton, Gebbie and Blenheim Formations; and it was later recognized that this tripartite division was also apparent in the Springsure area, where an almost complete sequence of Back Creek Group had been mapped as many distinguishable formations. Hence the three formations were raised to subgroup rank, and the names and concepts applied throughout the basin.

Since the three subgroups are not continuous in outcrop through the basin, this extension needs to be justified. Justification rests on four grounds, which together are thought adequate though no single one is conclusive.

First, the exposed thicknesses of the subgroups and the pattern of their surface distribution indicate that they are almost certainly continuous at depth: the Blenheim Subgroup in particular is concealed only for short distances.

Secondly, the subdivisions can be correlated throughout the basin by their faunal content. Dickins (in Dickins, Malone, & Jensen, 1964; Malone et al., 1969) distinguished four faunas in the northern part of the basin, of which Faunas II, III, and IV coincide with the boundaries of the subgroups erected in the same area. The faunas can be recognized throughout the basin.

Thirdly, the gross lithology of each subgroup is generally similar throughout the basin; and, more importantly, certain lithological changes occur everywhere at about the same stratigraphic level. For example, in the middle of the Gebbie Subgroup, a marine mudstone lies between paralic sandstones in the Springsure area; a marine sandstone between coal measures near Collinsville, and deeper water siltstone between shallow marine sandstone south of Collinsville. The change, according to the palaeontological evidence, took place at about the same time throughout the basin, and apparently signifies a marine transgression, followed by regression.

Lithological changes at the boundaries of the subgroups, which are roughly contemporaneous, also show a similar relationship throughout the basin; though of course over such a broad depositional area lithology varies laterally. Such lithological changes warrant the use of local formation names, but do not invalidate the concept of the subgroups as basin-wide units.

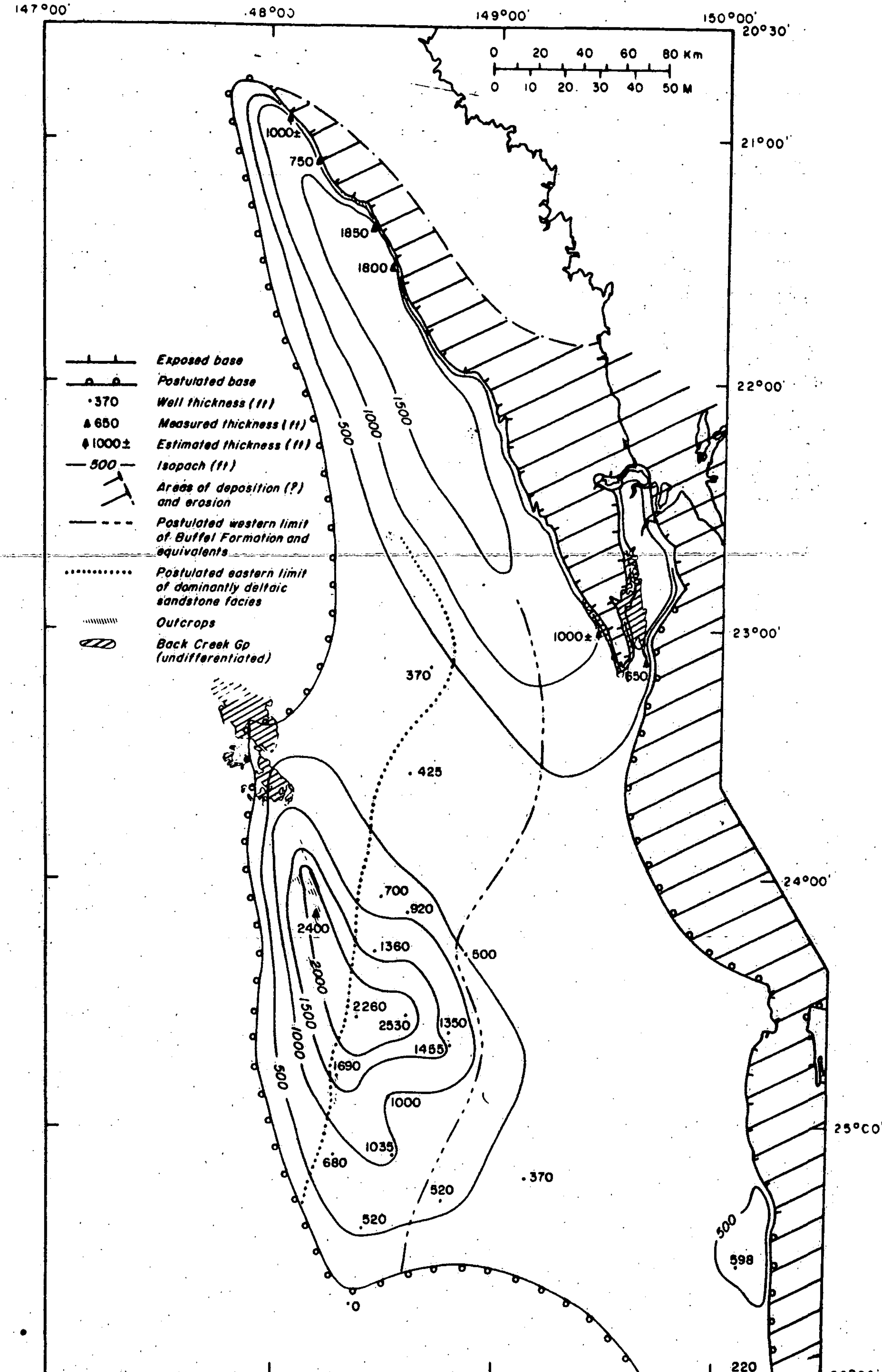
Fourthly, subsurface data, particularly from petroleum exploration wells, have helped to bridge the gap between outcrops and confirm the continuity of the group and subgroups. Well data have enabled the exposed units of the Springsure area to be traced far to the east and north; and seismic and limited well data on the sequence below the Mimosa Syncline confirm the continuity of the Back Creek Group between the Springsure and Theodore-Cracow areas.

Deposition of the Back Creek Group began in the Lower Permian, possibly in early Artinskian, and continued into the Upper Permian. It was generally laid down in a marine environment, though brackish and even freshwater environments existed at times around the margins of the basin. Most of the main fossils in the Bowen Basin sequence (Faunas II, III, and IV) are contained in the group.

TIVERTON SUBGROUP

The formations of the Tiverton Subgroup are listed in Table 6 together with brief descriptions of their lithology, relationships, distribution, type area, and important references. The distribution of the Tiverton Subgroup is shown in Figure 9 and the lateral relationships between the formations are diagrammatically presented in Figure 10.

The Tiverton Subgroup consists essentially of four overlapping or interfingering lithofacies: limestone, limestone/clastic, mudstone, and deltaic sandstone. The limestone facies in the southeast (the Buffel Formation) consists of a thin sequence of limestone which contains only a small proportion of fine terrigenous detritus and some coarse detritus at the base. The lithology and the type of thick-shelled brachiopods and pelecypods present, including abundant Eurydesma, suggest deposition in



To accompany report 1971/64

Q/A 348

Fig.9 Distribution of the Tiverton Subgroup

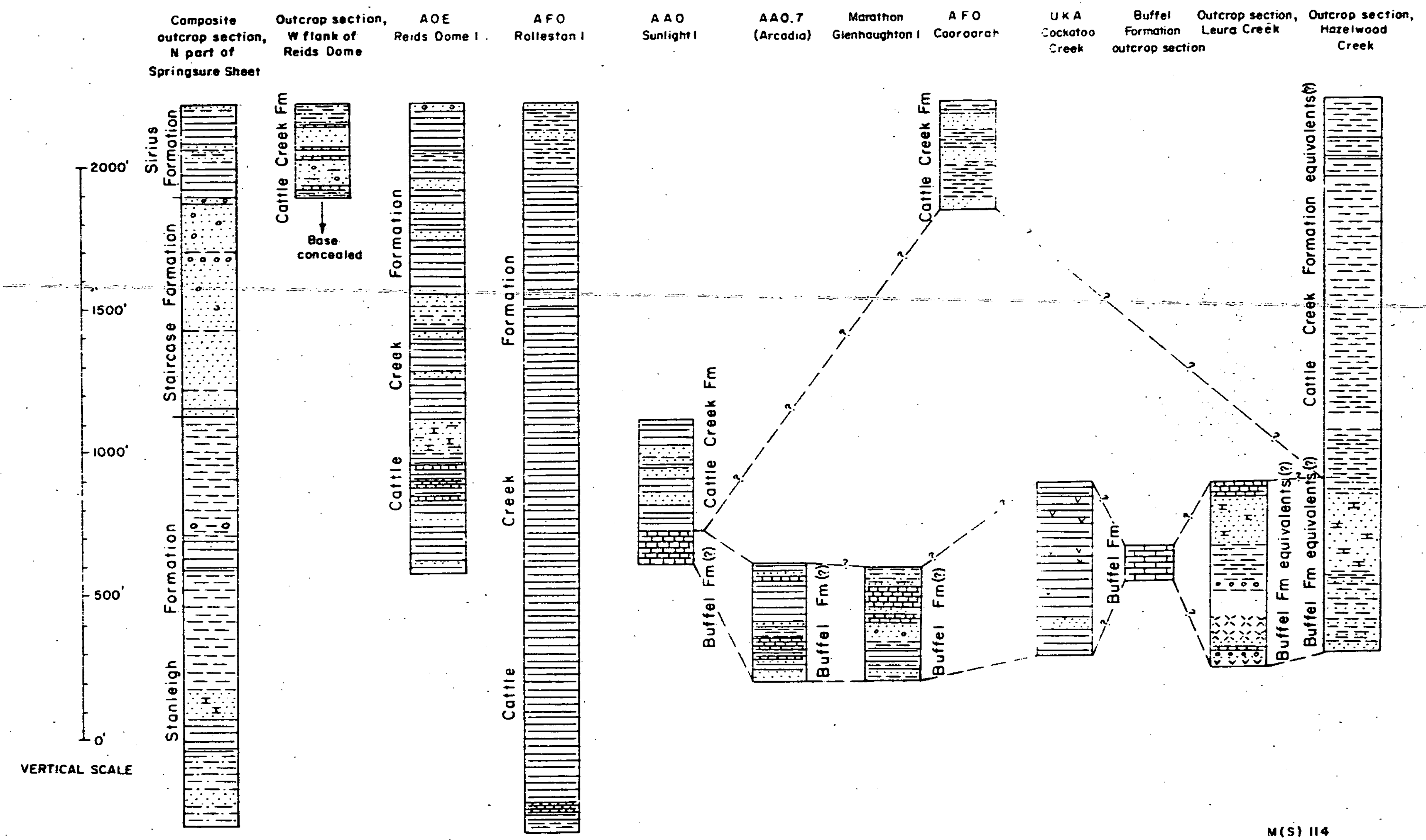


Fig.10 SECTIONS OF THE TIVERTON SUBGROUP TO ACCOMPANY RECORD 1971/64

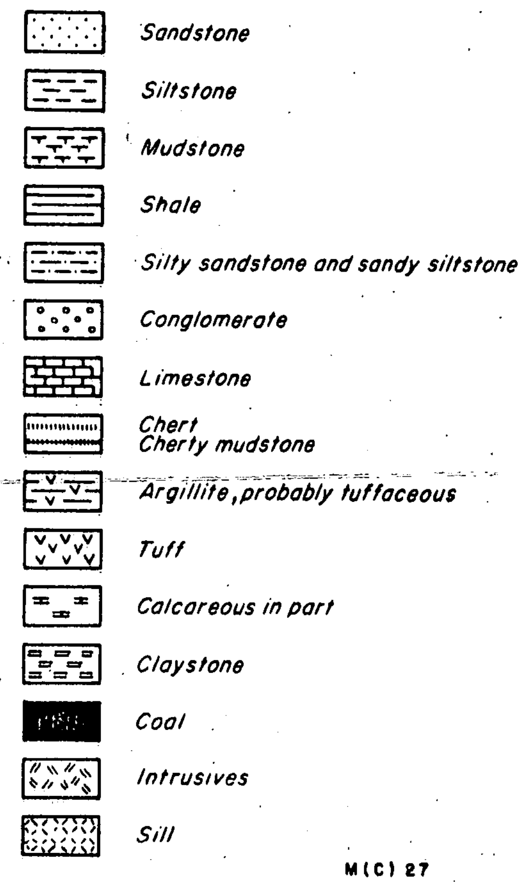


Fig 11 To accompany record 1971/64

SYMBOLS USED IN COLUMNAR SECTIONS

cold shallow water at a considerable distance from land. To the south, the Buffel Formation contains a greater proportion of clastics, mainly derived from volcanics. To the north in the vicinity of the Broadsound Range the sequence consists mainly of limestone with some volcanic rocks and volcanolithic sediments. Farther north, the basal part of the Tiverton Subgroup, which is equivalent to the Buffel Formation, consists of sandstone with numerous interbeds of calcareous sandstone, coquinite, and limestone. The change from the limestone facies of the Buffel Formation to the limestone/ clastic facies in the north reflects the persistence of vulcanism in the Broadsound Range area and the proximity of a clastic provenance in the north.

The postulated western limit of the Buffel Formation as shown on Figure 9 is based on limited subsurface data. In the wells, the Buffel Formation apparently rests unconformably on pre-Permian basement or eroded Reids Dome Beds.

In the AAO 7 (Arcadia) and Glenhaughton 1 wells, near the southwestern limit of the Buffel Formation, the sequence contains conglomerate and other clastics in addition to limestone. The clastics were probably derived from a southern provenance area. Farther north, the Buffel Formation in Sunlight 1 consists almost completely of limestone. The Sunlight area was apparently beyond the reach of clastics from the southern source, and the clastics from the western source were trapped in the rapidly subsiding Denison Trough. The Buffel Formation in the west unconformably overlies pre-Permian basement or is possibly unconformable on eroded Reids Dome Beds: an unconformable relationship to the Reids Dome Beds is suggested in AAO 7 (Arcadia).

Farther west, the mudstone represented by the Cattle Creek Formation, transitionally succeeded the Reids Dome Beds. The basal part of the Cattle Creek Formation is probably a time equivalent of the Buffel Formation. Later, as deposition and subsidence continued, the depositional area of the mudstone extended to the east and the Cattle Creek Formation overlapped the Buffel Formation as in the Sunlight 1 well. In Figure 9 the mudstone facies occupies part of the area between the deltaic sandstone and the Buffel Formation and its equivalents; it interfingers with the deltaic sandstone to the west and overlaps the Buffel Formation to the east, though it generally thins in that direction. The mudstone sequence at the top of the Tiverton Subgroup in the northern part of the basin is similar to the Cattle Creek Formation and may be continuous with it.

The deltaic sandstone is confined to the north and west of the Denison Trough and possibly extends north onto the Comet Ridge. The provenance was mainly to the north and west; a small number of cross-bedding measurements made in the Staircase Sandstone suggest a westerly provenance as in the overlying Gebbie Subgroup.

This sandstone crops out best in the Springsure Anticline where the Tiverton Subgroup consists of the Stanleigh Formation, Staircase Sandstone, and Sirius Formation. Recently, Power (1966) has suggested that the Soaircase Sandstone and a lower sandstone sequence (the Riverstone Sandstone Member of Power, 1966) within the Stanleigh Formation represents the distal portions of sandstone tongues which interfinger with the mudstone of the Cattle Creek Formation. Power has therefore revised the nomenclature. He considers that the Tiverton Subgroup here consists of only the Cattle Creek Formation, which comprises from top to bottom, the Sirius Mudstone Member, the Staircase Sandstone Member, a middle mudstone member, the Riverstone Sandstone Member, and a lower mudstone member.

In his paper, Power presents a diagrammatic north-south section which shows the mudstone units lensing out to the north. This is in agreement with our field observations, although the sequence in the north is poorly exposed. In a general way, the data suggest that a largely homogeneous mudstone unit (the Cattle Creek Formation) is replaced to the north and west(?) by a possibly homogeneous sandstone unit. The Stanleigh-Staircase-Sirius sequence, exposed in the Springsure Anticline, apparently represents the zone of interfingering between the mudstone and sandstone units. Thus, the Staircase and Riverstone Sandstones are regarded as tongues of the sandstone unit and not as members of the Cattle Creek Formation; the mudstone units could be members of the Cattle Creek Formation. For this reason, Power's nomenclature is unacceptable.

In the absence of sufficient data to name and define the sandstone unit, the existing nomenclature of Stanleigh Formation, Staircase Sandstone, and Sirius Formation will be used here for the sequence in the Springsure Anticline. Farther north, the Tiverton Subgroup was not subdivided.

The Tiverton Subgroup in the northern part of the Bowen Basin consists of a limestone/clastic sequence at the base overlain by mudstone. Most of the information on these units was obtained in the Strathmuir Synclinorium and western flank of the Connors Arch. The clastics in the lower unit are interbedded with tuff and tuffaceous sandstone around the Broadsound Range and in the Strathmuir Synclinorium. Farther north, the clastics include considerable lithic sandstone which was possibly derived from the Lizzie Creek Volcanics. The western limit of the limestone/clastic facies is concealed beneath sediments of the Gebbie and Blenheim Subgroups; it may have been a basal sequence which was laid down over most of the northern depositional area after the marine transgression. The limestone/clastics facies was succeeded by a poorly exposed mudstone unit which at least superficially resembles the Cattle Creek Formation. It is not known whether clastic equivalents of the mudstone extend beneath the younger sediments in the western part of the trough.

Tectonics and Sedimentation

The Buffel Formation is relatively thin around the margins of the basin, and this was probably maintained throughout its depositional area, including most of the postulated ridge separating the Reids Dome Beds from the Camboon Andesite. The ridge had been peneplaned by the time deposition of the Reids Dome Beds was completed, and it apparently subsided as a single block together with the Auburn Arch. The seismic surveys over the Mimosa Syncline do not reveal any evidence of thick linear wedges of the Tiverton Subgroup; this suggests uniform subsidence and sedimentation. This Lower Permian stable block was continuous with the Comet Ridge to the northwest which was also an area of slow subsidence and thin sedimentation, the sediments mainly being supplied from the northwest. It was flanked to the southwest by the Denison Trough which continued to be a zone of active subsidence and sedimentation. The sea gained access to the Denison Trough by transgressing across the stable block from the northeast; there may also have been a tenuous connexion southwards through the Sydney Basin. The Yarrol Basin to the east of the stable block consists of a zone of linear belts which have been tectonically active during and since the Lower Permian. The stable block probably extended as far north as the Broadsound Range, which represents the northern limit of non-deposition or deposition and erosion during the late Lower Permian. Here the stable block descended gradually into the northern depositional downwarp, which had direct access to the open sea. This downwarp was subsequently deformed, mainly by uplift of the Connors Arch, and now consists of two elongate, almost separate, belts of sediments.

Deposition of the Tiverton Subgroup in the Denison Trough was mainly confined to the area of maximum sedimentation of the Reids Dome Beds. The Tiverton Subgroup is not preserved west of the trough and the facies distribution suggests that deposition did not extend far to the west or northwest.

The northern depositional area was a broader, less elongate, downwarp than the Denison Trough and received a thinner sequence of sediments.

GEBBIE SUBGROUP

The late Lower Permian Gebbie Subgroup is well developed in the Denison Trough and in the northern part of the Bowen Basin; it thins across the intervening Comet Ridge, and is represented by a thin sheet of sandstone west of the Denison Trough. It is not present in the southeastern part of the Bowen Basin. The distribution and postulated depositional environments of the subgroup are shown on Figure 12. The formations within the subgroup are described in Tables 7, 8, and 9 and the lateral variations and relationships of the formations are illustrated in Figure 13.

Relationships to Underlying Rocks

The Gebbie Subgroup transitionally succeeded the Tiverton Subgroup in the Denison Trough. The trough subsided actively during the Lower Permian, and sedimentation was probably continuous from one unit to the next. To the west, the Colinlea Sandstone disconformably overlies the Reids Dome Beds. The basal beds of the Colinlea Sandstone are correlated with the middle member of the Aldebaran Sandstone on lithological and palynological data, and the western part of the Bowen Basin was apparently subject to erosion during the early part of Gebbie Subgroup time.

In the north, the contact between the Gebbie and Tiverton Subgroups is not exposed on the west flank of the Connors Arch. The base of the Gebbie Subgroup consists of micaceous coarse siltstone with carbonaceous streaks, grading up rapidly into silty sandstone and then quartzose sandstone. This sequence may transitionally succeed the roughly laminated grey and blue siltstone at the top of the Tiverton Subgroup, and subsidence and sedimentation were probably continuous throughout the Permian. The Gebbie Subgroup overlapped the Tiverton Subgroup to the north and west. The Collinsville Coal Measures, which represent the subgroup in the northwest, disconformably overlie the Lizzie Creek Volcanics. The most probable correlation of the coal measures with the type area of the Gebbie Subgroup indicates that the basal beds of the subgroup are either absent or very poorly represented at the base of the coal measures. Similar relationships obtain on the western margin of the Denison Trough, where expansion of the depositional area also took place after the beginning of deposition of the Gebbie Subgroup.

The absence of the Gebbie Subgroup in the southeastern part of the basin is due to non-deposition or to erosion. Well data indicate that the Gebbie Subgroup thins rapidly to the east of the Denison Trough. Part of the thinning may be the result of erosion below disconformities, but it seems that the thin equivalent of the subgroup deposited in the southeast was later removed by erosion.

The change from the Tiverton Subgroup to the Gebbie Subgroup was the result of a moderate regression from a marine environment to shallow marine or paralic. The area of deposition was unchanged initially, but later expanded to the west of the Denison Trough and north and west in the northern part of the basin. Apparently the supply of sediment matched the rate of subsidence within the basin, thus maintaining the shallow marine

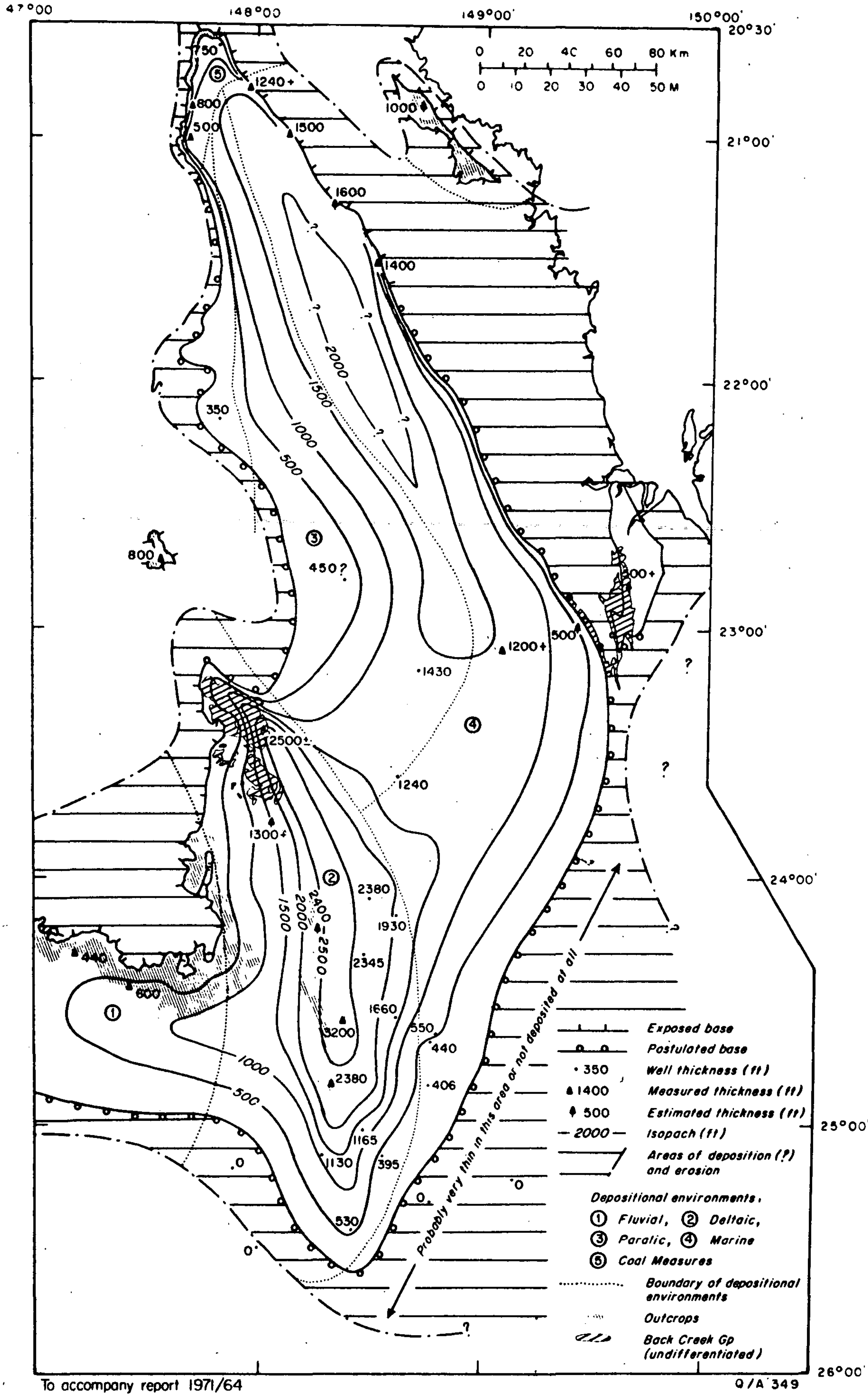


Fig. 1c Distribution of the Gebbie Subgroup and equivalents

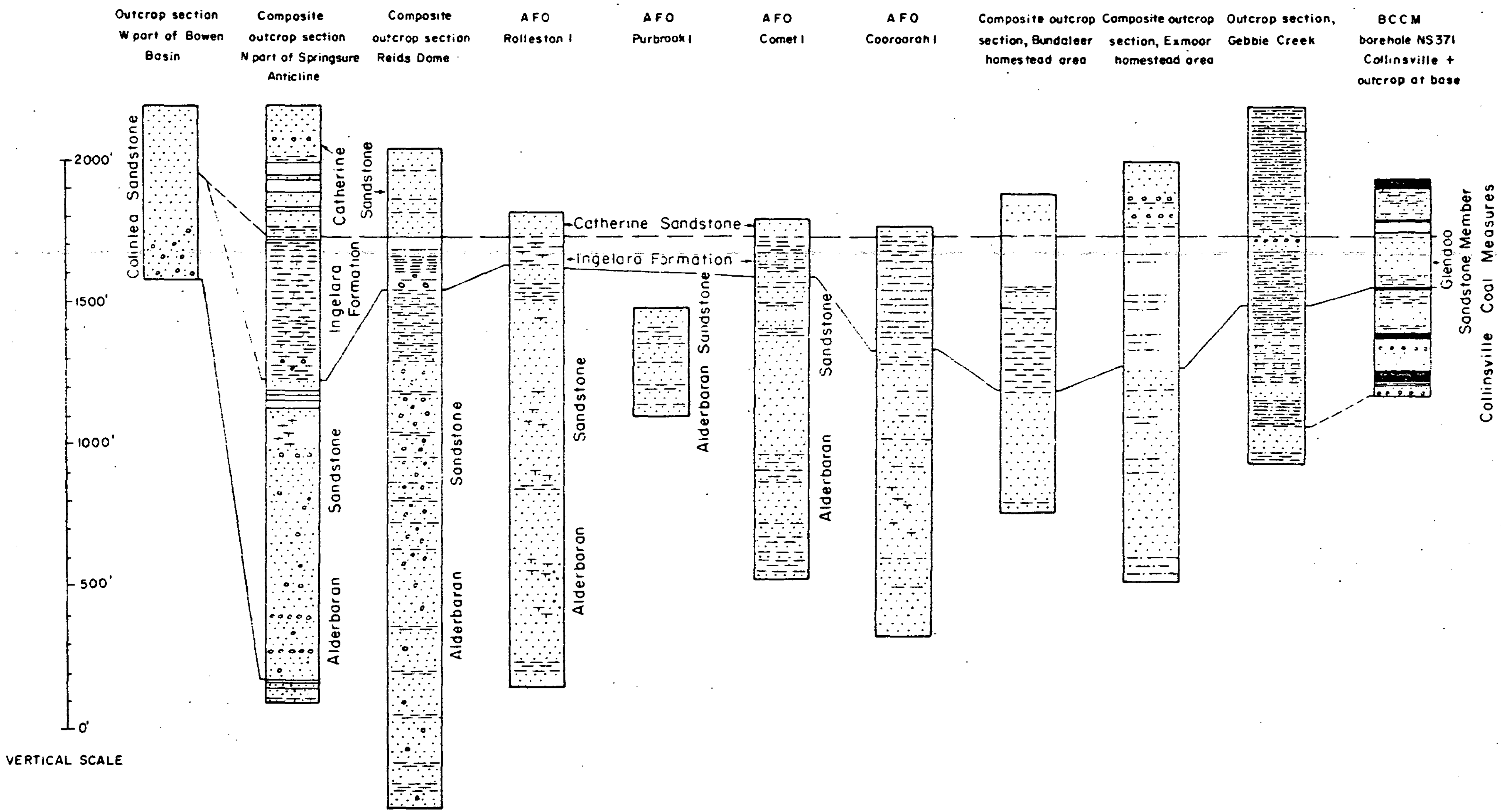


Fig. 13 SECTIONS OF THE GEBBIE SUBGROUP TO ACCOMPANY RECORD 1971/64

environment, and the marginal areas west of the Denison Trough and north and west of the northern part of the basin subsided proportionally to permit accumulation of sediments in a terrestrial environment.

Fluvial Environment of the Western Bowen Basin

The postulated depositional environments (see Fig. 12) are based on limited field observations and petrography. The Colinlea Sandstone was laid down in a fluvial environment in the southwest. Petrological (Mollan et al., 1969; Bastian, 1965b) and palynological data (Evans, 1966b) indicate correlation of the Colinlea Sandstone with most of the Aldebaran Sandstone and the Catherine Sandstone; no equivalent of the Ingelara Formation can be recognized. The Colinlea Sandstone is an almost unfolded, uniformly thin sheet of sand, ranging from 135 to 240 m thick. It represents a period of slow sedimentation compared to the great thickness of sediment deposited in the adjacent Denison Trough during the same time interval. The Colinlea Sandstone was apparently laid down on a large slowly subsiding stable shelf.

The sediments were derived from the north (Anakie Metamorphics, Retreat Granodiorite, Drummond Basin sequence) and from the south (now concealed Timbury Hills Formation and granite penetrated in petroleum exploration wells). Variations in the composition of the sandstone indicate that particular provenance areas were the predominant source of detritus at times. Measurement of cross-bedding dip directions are equivocal (Mollan et al., 1969), but the distribution and relationships of the Colinlea Sandstone to the Gebbie Subgroup in the Denison Trough indicate that the main direction of sediment transport was across the shelf into the trough. The absence of an equivalent of the Ingelara Formation within the Colinlea Sandstone may be due to a disconformity. The Ingelara Formation was apparently laid down during a period of subsidence of most of the Bowen Basin, but the transgression may not have affected the shelf west of the Denison Trough. The Ingelara Formation may have been formed of sediment derived directly from both the northern and southern source areas and not by sediment moving across the Colinlea Sandstone shelf. The conglomeratic mudstone in the south and most of the other sediments in the Ingelara Formation appear to have undergone little reworking, and it seems unlikely that they were transported across the shelf. The shelf area in which the Colinlea Sandstone was laid down was probably the site of local alluvial aggradation and degradation during the period when the Ingelara Formation was deposited.

Deltaic Environment of the Denison Trough

The greatest thickness of the Gebbie Subgroup was laid down in the Denison Trough. The basal sandstone member of the Aldebaran Sandstone was deposited in a deltaic environment, probably partly brackish, which gradually replaced the marine environment of the Cattle Creek Formation. Thick interbeds of siltstone and mudstone, locally including coal seams, indicate a greatly reduced supply of sand and coarser detritus at times.

The middle conglomeratic member of the Aldebaran Sandstone represents a period of rapid sedimentation of mainly sand size and coarser detritus, which began about the same time as deposition of the Colinlea Sandstone. The supply of sediment matched the rate of subsidence of the Denison Trough so that a deltaic, probably partly brackish, environment was maintained despite an increase in the area of subsidence. The increase in average grainsize from the basal member to the middle member suggests more vigorous uplift and erosion of the source areas. The predominant quartz and quartz sandstone clasts of the conglomerate in this member were derived from a different source from that of the conglomerates in the Cattle Creek and Ingelara Formations.

The conglomerate clasts resemble some of the rocks exposed in and around the Drummond Basin to the northwest, and the cross-bedding measurements indicate a northwesterly source.

The upper member of the Aldebaran Sandstone, which consists of interbedded quartzose sandstone and mudstone, was laid down in an environment transitional between the preceding brackish environment and the deltaic marine environment of the succeeding Ingelara Formation. The abundance of worm tracks and the presence of oscillation ripple marks suggest deposition in the tidal zone. The rate of subsidence was apparently slightly faster than the rate of sedimentation so that the depth of water gradually increased.

The Ingelara Formation consists mainly of poorly sorted and poorly bedded conglomeratic sandy siltstone and mudstone laid down in relatively deep water where there was little effective reworking. The presence of calcareous concretions containing abundant shelly fossils indicates that the sea had unrestricted access to the area at this time.

On the southern margin of Reids Dome the siltstone contains some angular boulders of granite, porphyritic volcanics, and low-grade metamorphics, which probably were derived from a southerly or southwesterly source area like the boulders in the Cattle Creek Formation. Boulders such as these are not known in the Aldebaran or Catherine Sandstones. Their origin is uncertain, but Hill (1957) and others have suggested that they are glacial erratics dropped from icebergs. Alternatively, they could have been produced by erosion of cliffs (to the south or southwest) and turbidity currents. Angular blocks are found in the sediments deposited during marine transgressions, particularly with widespread coquinite beds such as the Big Strophalosia Zone, but they are not common in the marine sediments between the coquinites.

The Catherine Sandstone marks the close of sedimentation in the Denison Trough. It was laid down in a shallow sea, but is transitional into the Ingelara Formation below. The formation consists of fine to medium-grained well sorted quartzose sandstone with thin siltstone interbeds. The planar bedding or low-angle cross-bedding, the relative abundance of heavy minerals, the good sorting, and the presence of scattered glauconite and marine fossils indicate deposition in a shallow marine environment where there was considerable reworking. The Catherine Sandstone is disconformably overlain by the Peawaddy Formation, and to the south it is overlapped.

Paralic Environment of Comet Ridge and Collinsville Shelf

Two depositional environments have been tentatively recognized east and north of the Denison Trough. There was a sandy paralic environment over most of the Comet Ridge and Collinsville Shelf, and a marine, partly shallow, environment over most of the eastern part of the Bowen Basin. The sandy paralic sediments extend for a short distance to the west on to the Capella Block, but apparently lens out beneath the overlying Blenheim Subgroup.

In the west the paralic sediments are concealed, but were penetrated in the Comet 1, Cooroorah 1, and Norwich Park Scout 1 wells. In the first two wells the sequence consists of a thick basal sandstone unit which can be correlated with the Aldebaran Sandstone and a thinner mudstone unit which is a probable correlate of the Ingelara Formation. The Catherine Sandstone is tentatively recognized in the Comet 1 well as a very thin sandstone, but is possibly not present in the Cooroorah well. Probably only part of the Aldebaran Sandstone equivalent was penetrated in Norwich Park 1. The Gebbie Subgroup is very much thinner on the Comet Ridge than in the Denison Trough. Most of the sediment must have been derived from the northwest as the Denison Trough would have trapped most of the sediment from the west. The Aldebaran Sandstone was laid down on the Comet Ridge during a period of slow subsidence with extensive reworking of the sediments. The finer material was winnowed out and transported farther southeast, and both the coarse and fine sediments were probably swept southwest into the Denison Trough. The extensive reworking may have been responsible for the diagenetic silicification of the quartzose Aldebaran Sandstone observed in the Cooroorah 1 and Norwich Park Scout 1 wells. In the Comet 1 well near the eastern margin of the paralic environment, the Aldebaran Sandstone includes thick intervals of siltstone and mudstone and very little diagenetically silicified sandstone.

Little information is available on the Gebbie Subgroup over most of the Collinsville Shelf. The coal measures intersected in water bores about 80 km north-northeast of Clermont appear to be stratigraphically below the basal beds of the Blenheim Subgroup. They are considered to be part of the Gebbie Subgroup and probably equivalent to the Collinsville Coal Measures. The coal measures were laid down in a terrestrial environment on the western margin of the paralic sea.

The thickness of the Gebbie Subgroup at the northern end of the Collinsville Shelf and on the west flank of the Connors Arch suggests that the slowly subsiding paralic environment on the Collinsville Shelf was relatively narrow compared with its extent on the Comet Ridge. This may have resulted in less diagenetic silicification of sandstone in this area.

Marine Environment of the Eastern Bowen Basin

The Gebbie Subgroup deposited in the marine environment in the eastern part of the Bowen Basin is exposed near the Mackenzie River, 56 km north of Bluff, and along the western flank of the Connors Arch. On the map equivalents of the subgroup are not separated from the Back Creek Group in the Strathmuir Synclinorium. The Gebbie Subgroup in the Mackenzie River outcrops consists of upper and lower sandstone units separated by siltstone.

Mackenzie River Area

The basal sandstone unit consists mainly of cross-bedded fine to coarse sandstone, most of which contains a large proportion of grains of volcanic rocks. The volcanic detritus was apparently derived from a source to the east. The cross-bedding indicates considerable current action, but the high proportion of labile constituents indicates little reworking of the sediments. The presence of rare scattered marine shelly fossils throughout the sandstone indicates a marine environment which was shallow at times. The cross-bedding may be related to tidal currents.

The distribution of the subgroup indicates that access to the open sea was restricted and this may have produced a concentration of tidal currents in this area. The middle unit is mainly siltstone and contains hard smooth calcareous fossiliferous nodules in places. Some of the fossils (e.g. Conocardium sp.) suggest deposition in a muddy environment below the depth of wave action, and the depth of water was probably much greater than during deposition of the basal sandstone. The fossils in the middle unit are similar to those in the Ingelara Formation of the Denison Trough, and the deeper water was probably the result of the marine transgression during which the Ingelara Formation was laid down. Comparison of the Mackenzie River section with the sequence in Cooroorah 1, 40 km to the west, suggests that the basal sandstone may be continuous with the Aldebaran Sandstone and the siltstone with the Ingelara Formation.

The upper unit in the Mackenzie River area is a poorly exposed sequence of relatively thin sandstone.

Strathmuir Synclinorium Area

The sediments of the Strathmuir Synclinorium correlated with the Gebbie Subgroup include fossiliferous calcareous volcanolithic sandstone and nodular siltstone. The problem of separating the Tiverton and Gebbie Subgroups in this area and about the southern end of the Connors Arch may be related to its position relative to the depositional environments. Throughout the Lower Permian, this part of the basin had direct access to the open sea and was continuously marine. The transgressions and regressions which altered the depositional environment and produced marked changes of lithology in most parts of the basin did not significantly alter the depositional environment in this area.

Western Flank of Connors Arch

The Gebbie Subgroup is concealed for about 160 km to the north of the Mackenzie River outcrops. Thereafter, it crops out on the west flank of the Connors Arch to near Collinsville. The subgroup contains three formations as in the Mackenzie River area.

The basal part of the lower unit consists of about 60 m of sandy siltstone, with some fossiliferous calcareous beds, which grades up into quartzose sandstone. The basal sequence was probably deposited during the transition from the deeper water environment of the Tiverton Subgroup. The basal beds are overlain by the Wall Sandstone Member, which consists of silicified cross-bedded and rarely ripple-marked quartzose sandstone. The member is about 30 m thick, and extends for about 50 km; a similar sandstone bed has been tentatively recognized throughout the outcrop area. The Wall Sandstone Member contains rare marine fossils and was apparently deposited in a shallow sea where there was considerable reworking of the sediments. It was possibly a sand bar. The overlying sandstones are less well sorted and less mature, and were possibly laid down in slightly deeper water. Some thin coal seams are present just above the Wall Sandstone Member, at the northern end of the belt. The coal may have been transported from elsewhere as the associated sediments contain abundant carbonaceous debris. If the coal was formed in situ, then a freshwater environment existed for at least a short while during deposition of the Gebbie Subgroup.

At the northern end of the belt the middle unit contains slightly more sandstone than siltstone. The rocks are similar to those in the units above and below, but siltstone and fossiliferous beds are more common. Farther south, the middle unit consists mainly of sandy siltstone which forms a valley between the sandstone ridges of the underlying and overlying units.

The upper unit is thickest in the north where it consists of about 120 m of sublabile sandstone, ripple-marked quartz sandstone, and thin siltstone interbeds. It thins to 75 m or less to the south where the basal unit thickens to slightly more than half of the entire subgroup.

Near the southern limit of the belt only the upper and lower units are exposed and both contain some richly fossiliferous horizons. The lithology is much the same as farther north.

The absence of grains of volcanic rocks in the sandstones distinguishes them from the beds in the Mackenzie River area; the change is probably due to differences in the provenance areas. The Gebbie Subgroup on the flank of the Connors Arch was probably derived from the north, and the abundance of sandstone in the coal measures indicates a copious supply of arenaceous material from the northern provenance. The sediments were transported by streams moving through or between the areas in which the Collinsville and Calen Coal Measures were deposited. Some of the sediment may have come from the west, but the distribution of the subgroup suggests that the axis of deepest subsidence in the north at this time may have been west of the Connors Arch (see Fig. 12), and thus relatively deep water would have trapped most of the sediment supplied from the west.

Coal Measure Environments

The Collinsville Coal Measures undoubtedly belong to the Gebbie Subgroup. The Calen Coal Measures, northwest of Mackay, are correlated with the subgroup because of their lithological similarity. They could have been deposited on the margin of the depositional area of the Gebbie Subgroup, as were the Collinsville Coal Measures. The coal measures encountered in water bores about 80 km north-northeast of Clermont appear to be stratigraphically below the Blenheim Subgroup, and are probably part of the Gebbie Subgroup (see also Veevers et al., 1964b). The Blair Athol Coal Measures were deposited in an isolated basin, but are possibly time equivalents of the Gebbie Subgroup.

Collinsville Coal Measures

The Collinsville Coal Measures comprise two sets of coal measures composed mainly of sandstone with some conglomerate, coal, and minor siltstone and carbonaceous mudstone, separated by a sequence of marine sandstone. The three units can be correlated with the three formations of the Gebbie Subgroup in the northern part of the basin. The conglomerate bed at the base of the coal measures rests on Lizzie Creek Volcanics and on Carboniferous volcanics and intrusives in the southwest. The conglomerate marks an expansion of the depositional area to the north and west; it is not present in the Gebbie Subgroup southeast of Collinsville where deposition continued after the Tiverton Subgroup was laid down.

The Collinsville Coal Measures were probably deposited in swamps, not far from the sea. The sandstone in the coal measures is similar to that in the Gebbie Subgroup to the south, but is generally finer in grain. The coal may have been formed in swamps at the back of a large delta or between the main distributary channels which carried the medium sized sand and coarser detritus into the sea. The fine sandstone, siltstone, and carbonaceous mudstone were probably deposited in flood-plains between the main distributaries which migrated laterally from time to time. Some of the coal seams are cut by washouts filled with conglomerate and coarse sandstone; the washouts were probably formed as a result of lateral migration of the distributary channels.

Webb & Crapp (1960) have suggested that the Bowen Seam may be autochthonous in the north and allochthonous in the south. The seams generally thicken to the north and thin to the south into the basin, whereas the sediments between the coal seams thicken towards the centre of the basin. The reworking of the coals, the variations in thickness, and the predominance of arenites suggest that the depositional area was not a broad flat coastal plain, but a surface which sloped gradually towards the basin. The swamps in which the coal was laid down may have formed behind sand bars distributed by longshore currents.

The marine sandstone in the middle of the Collinsville Coal Measures was laid down when the sea transgressed the delta. In the marine environment individual beds can be traced for considerable distances, and some thin fossiliferous sandstone beds, 15 cm to about a metre thick, persist along strike for several kilometres.

Calen Coal Measures

The Calen Coal Measures consist of about 300 m of coarse quartzose sandstone, mainly in thick cross-bedded sets, thinly interbedded sandstone and siltstone, siltstone grading laterally into soft brown claystone, and thin coal seams. They contain the Permian plants *Glossopteris* and *Vertebraria* but no marine fossils, and unconformably overlie the Carmila Beds and Lizzie Creek Volcanics. The Calen Coal Measures are situated about 50 km from the nearest outcrops of the Gebbie Subgroup, which is the only Permian unit containing similar rock types. The coal measures are largely fluvial, but were partly laid down in lakes or local swamps.

Blair Athol Coal Measures

The Blair Athol Coal Measures are described in Veevers et al. (1964b). They consist of about 240 m of sandstone, coal seams, carbonaceous claystone and shale, and a little fine conglomerate. A basal pebble conglomerate is locally present. The main coal seam has a maximum thickness of 33 m. The coal measures were almost certainly laid down in an isolated basin within the Anakie Metamorphics. The basin is about 16 km long by about 3 km wide in the north and about 13 km wide in the south. The surface of the underlying Anakie Metamorphics is very irregular in places and rises steeply to the north and gently to the south. The coal seams interfinger with the sediments around the margins of the basin. The great thickness of individual seams suggests that the coal measures accumulated during a period of steady subsidence. There are no tectonic breaks in the sequence and the subsidence was probably of regional extent. The Blair Athol Coal Measure basin is in line with the long axis of the Denison Trough, where maximum subsidence occurred during deposition of the Gebbie Subgroup. For this reason it is suggested that the Blair Athol Coal Measures are time equivalents of the Gebbie Subgroup. It is possible that the Blair Athol basin was formed at the same time as the Tiverton Subgroup or Reids Dome Beds, but the Denison Trough was not then so elongated in the direction of the basin as in Gebbie Subgroup time. Palynological work (Evans, 1966c) suggests that the Blair Athol Coal Measures may be correlated with the Aldebaran Sandstone, but the evidence is not conclusive.

Tectonics

The main tectonic feature in Gebbie Subgroup time was the elongate Denison Trough which was the locus of maximum sedimentation. The northern depositional basin is elongate on Figure 12, but this is mainly due to post-depositional uplift and erosion of the Gebbie Subgroup adjacent to the Connors Arch. The Gebbie Subgroup was probably laid down as a sheet of fairly uniform thickness over most of Connors Arch and the area to the east. The whole of the northern part of the Bowen Basin and the area to the east probably subsided more or less uniformly. It was separated from the Denison Trough by the Comet Ridge where subsidence and sedimentation were less pronounced.

In the southeast any sediments laid down were later removed by erosion. The well sections indicate that little sediment was derived from this area during the deposition of the Gebbie Subgroup. The area was apparently part of a large stable peneplaned block, which may have been slightly submerged at times.

The eastern limits of the Gebbie Subgroup are not clear. Presumably, the sea had direct access to the basin through the Strathmuir Synclinorium and to the north. The disconformity between the basal Tiverton Subgroup and the Blenheim Subgroup south and east of the synclinorium indicate that it was probably an area of non-deposition. The only time equivalents of the Gebbie Subgroup to the east are part of the Berserker Beds in an elongate northerly trending graben, east of Rockhampton. The Berserker Beds are mainly volcanics and coarse clastics laid down near their source. The graben and the Bowen Basin to the west were probably separated by a land area during most of the late Lower Permian.

BLENHEIM SUBGROUP

The Blenheim Subgroup, the youngest subgroup in the Back Creek Group, was deposited in the early Upper Permian (Kazanian) during a major marine transgression which overlapped the Gebbie Subgroup to the west and southeast. Most of the changes in lithology are the result of the marine transgression, but the Blenheim Subgroup is also characterized by the presence of acid volcanic detritus and tuff. There was also a major shift in the locus of maximum sedimentation. The thickest part of the Blenheim Subgroup was laid down in a trough extending from the north to the southeastern corner of the basin, and in an eastern extension now largely occupied by the Gogango Overfolded Zone (see Fig. 14). The greatest known thickness of the Blenheim Subgroup or its equivalents is more than 2100 m of Moah Creek Beds (Kirkegaard, Shaw, & Murray, 1966, and in prep.) in the Rockhampton Sheet area within the eastern extension. More than 1500 m of sediment was laid down in the main trough whose elongation and asymmetry are largely the result of post-depositional uplift of the Connors and Auburn Arches. The Blenheim Subgroup thins steadily to the west and forms a uniform blanket across the Denison Trough which had apparently ceased subsiding relative to areas on either side.

The Blenheim Subgroup is more widespread and displays much more lateral variation than the preceding subgroups. The constituent formations, including some unnamed units, are briefly described in Table 10 and some of their lateral relationships are illustrated in Figure 15.

In the southeast, where the subgroup comprises the Oxtrack, Barfield, Flat Top, and Banana Formations, lutites, with thick lenses of tuffaceous clastic sediments, were predominant. To the west the lutite province grades into a lutite/arenite/coal measure province on the Comet Ridge, and into a lutite/arenite province, containing significant volcanic detritus and local volcanic rocks, in the Denison Trough and western part of the Bowen Basin; to the north the lutite province grades into a flysch(?) province (Boomer Formation).

The Boomer Formation grades into more conglomeratic sediments which were possibly laid down in a synorogenic molasse province to the east of the map area. The arenites in all the provinces consist predominantly of lithic sandstones which were possibly derived from volcanics; quartz-rich sandstone is more common on the Comet Ridge and in the west.

There was also a lutite/quartzose arenite province to the north of the flysch province on the west flank of the Connors Arch, and a paralic quartzose arenite/lutite province to the west on the Collinsville Shelf. Towards the close of deposition of the Blenheim Subgroup deltaic coal measures were laid down on adjacent parts of the Comet Ridge and Denison Trough. Quartz-rich arenites predominate in all the northern provinces. This change reflects the difference between the predominant volcanolithic detritus supplied by the provenance area to the east and south and the predominant quartz-rich detritus supplied by the provenance area to the north and west.

Lutite Province

The oldest sediments in the lutite province are the thin neritic limestone and calcilutite of the Oxtrack Formation. The abundance of fossils suggests deposition in a shallow sea, somewhat warmer than the sea in which the disconformably underlying Buffel Formation was laid down. The Oxtrack Formation was succeeded by thick massive mudstone of the Barfield Formation.

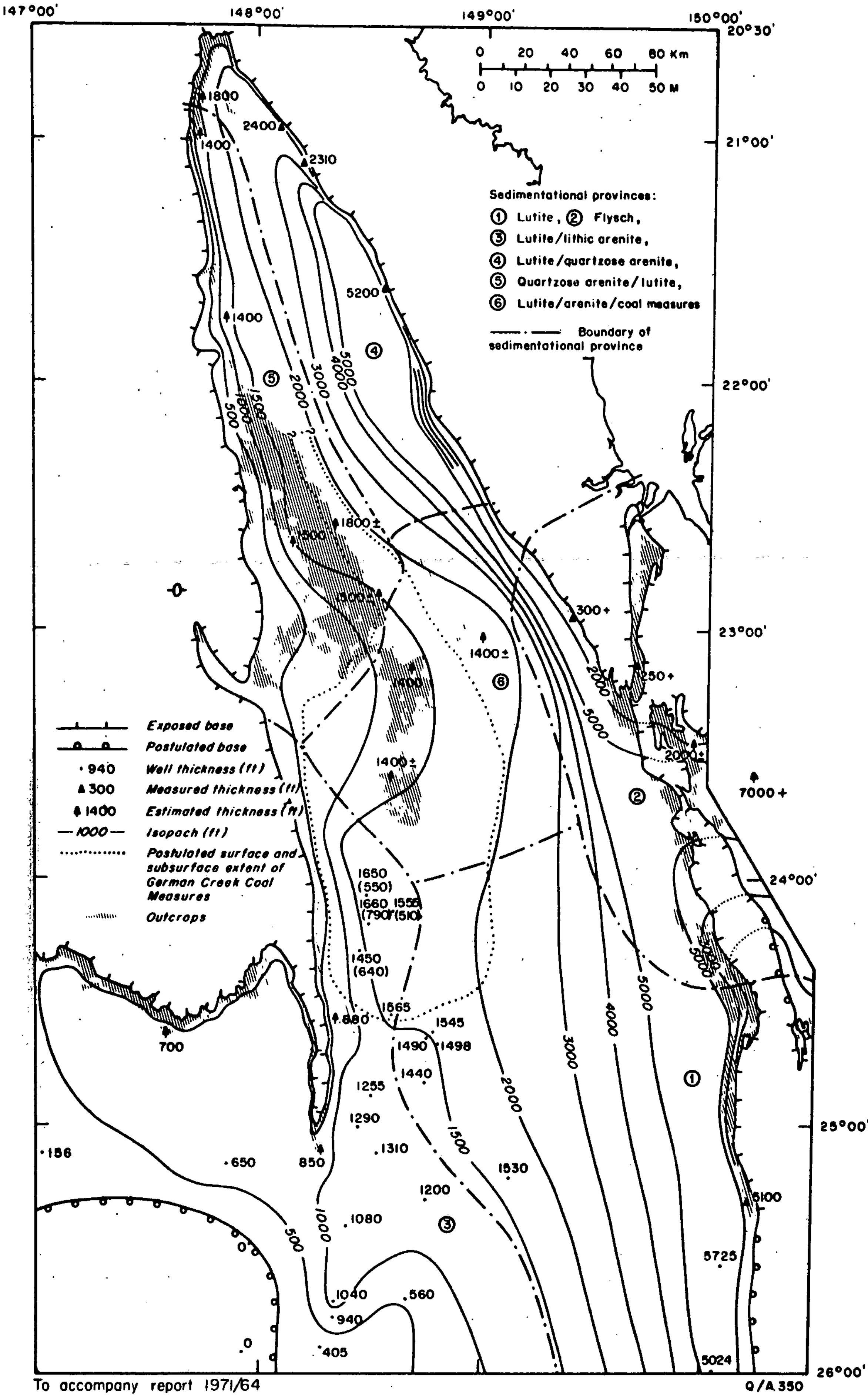
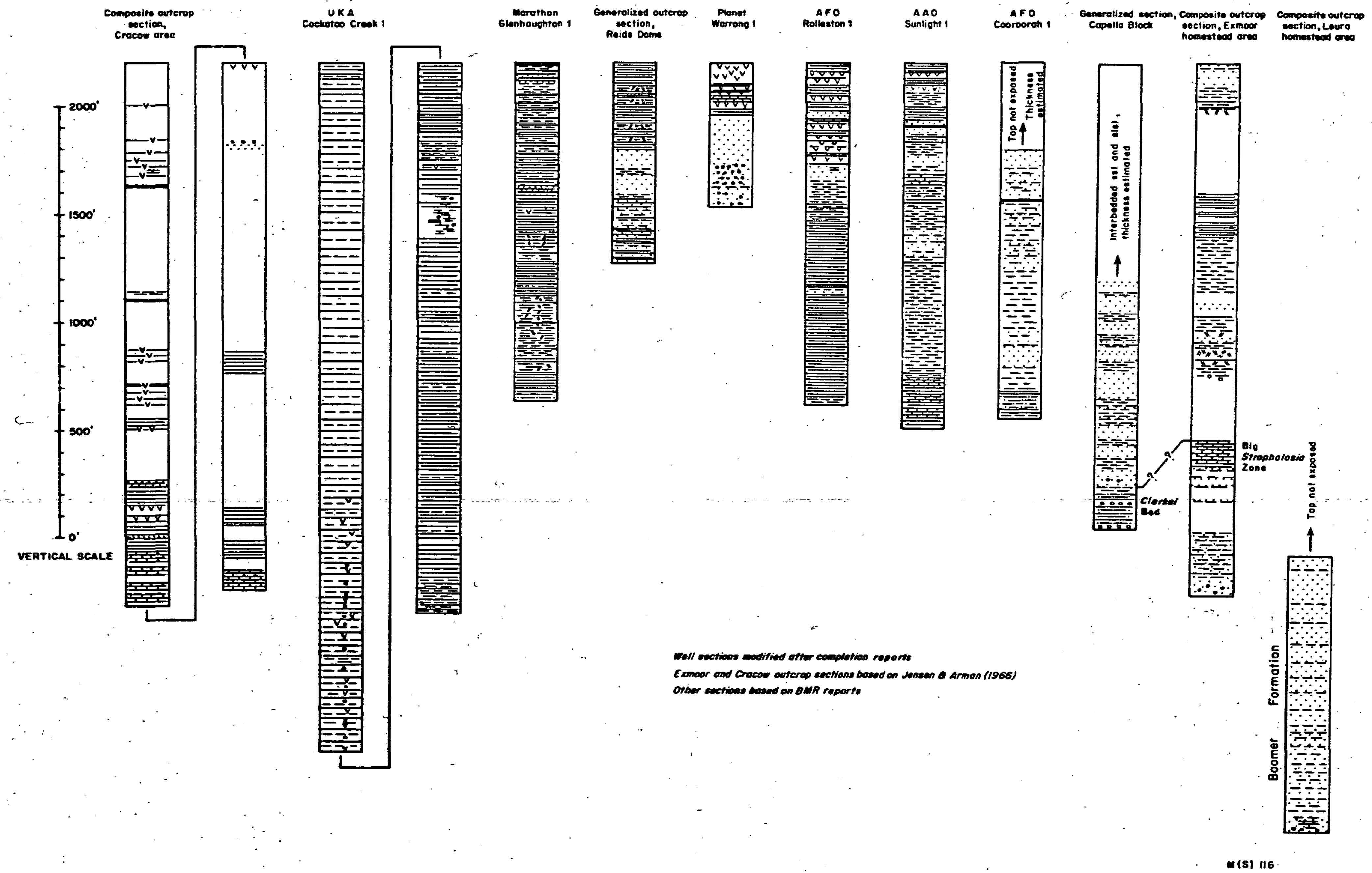


Fig. 14 DISTRIBUTION OF THE BLENHEIM SUBGROUP



Sections of the Blenheim Subgroup

Fig. 15

This formation contains minor beds of lithic arenite and in the upper part some beds of tuff and agglomerate and lava flows; calcareous concretions are common throughout. Fossils are abundant in some of the calcareous concretions and in beds of calcareous mudstone. Glendonites are common in the upper part of the formation. The volcanics occur in at least two stratigraphic levels, and can probably be correlated with the thick volcanics intersected in the Cockatoo Creek 1 well. The upper part of the Barfield Formation, including the volcanics, was originally called the Acacia Formation (Derrington et al., 1959), but it is now regarded as a volcanic member within the Barfield Formation. The Barfield Formation was probably laid down in moderately deep water. The presence of black pyritic mudstone indicates a reducing environment at times. Most of the fossils are abraded and worn, and were probably transported for some distance. Some of the calcilutite beds contain corals, brachiopods, and worm tubes and were presumably laid down in shallow well oxygenated water. The neritic environment of the underlying Oxtrack Formation apparently migrated southeast during deposition of the Barfield Formation. The environmental significance of the glendonites is not clear, though it has been suggested that they indicate glacial conditions (see Carey & Ahmad, 1961).

The Flat Top Formation consists of tough blue or buff mudstone containing numerous thin layers of blue mudstone with intricately contorted laminae. Poorly sorted lithofeldspathic sandy siltstone containing a high proportion of volcanic detritus is interbedded with the mudstone in places. Marine fossils are more abundant in the north; in the south, fossil wood impressions are common near the top of the formation, and still farther south thin coal seams are present in the Cockatoo Creek 1 well. The Flat Top Formation was possibly deposited in a partly marine and partly freshwater environment. The fine grainsize of the sediments suggests a distant provenance area or one of low relief.

The Banana Formation is lenticular; it consists of mudstone, similar to the Barfield Formation, and is restricted to the area near Banana. It may have been deposited in a partly non-marine environment. J.F. Dear (pers. comm.) considers the Banana Formation to be part of the Flat Top Formation.

The presence of a thin lutitic sequence of the Blenheim Subgroup in the Glenhaughton 1 and Purbrook South 1 wells indicates that the lutite province extended a considerable distance to the west. As the proportion of arenite increases to the west the lutite province grades into the lutite/ arenite province.

Lutite/Arenite Province

In the lutite/arenite province the Peawaddy Formation is overlain by the Black Alley Shale. To the southwest, beneath the Great Artesian Basin sequence, the Peawaddy Formation becomes more arenaceous and disconformably overlaps progressively older rocks; in the far southwest, it unconformably overlies pre-Permian rocks*.

The Peawaddy Formation consists mainly of mudstone and sandy siltstone, but lithic sandstone forms about half of the upper part of the unit. Coquinitic lenses of the Mantuan Productus bed occur at the top of the formation in places. The basal part of what we recognize as Peawaddy Formation in wells south of the exposed part of the Denison Trough includes sandstone, pebbly sandstone, and conglomerate, and the same rock types are predominant in the Peawaddy Formation in the far southwest of the basin. Marine fossils are particularly abundant in the Mantuan Productus bed; they are common in some of the lower beds and are also scattered throughout the formation. The fossils indicate a marine environment. The basal conglomeratic unit in the southwest reflects the transgressive nature of the marine environment.

The arenaceous basal unit crops out poorly around the Springsure Anticline and northern end of Reids Dome. This is also the area of maximum development of the Catherine Sandstone which is truncated beneath the Peawaddy Formation farther south. Sedimentation was possibly nearly continuous in this area in Gebbie Subgroup time, although the Peawaddy Formation and Catherine Sandstone may be disconformable.

* The stratigraphic synthesis is based on correlation of subsurface data with the exposed section in the Denison Trough and is discussed in detail in Mollan et al. (1969). Most recent workers agree on the stratigraphy of the exposed section, but not all agree on the subsurface stratigraphy. The correlation presented here fits the available stratigraphical, lithological, and palaeontological data reasonably well, but is certainly not proven. The alternative correlations contradict the palaeontological data to some extent, generally on the grounds that the faunal changes reflect environmental rather than evolutionary changes. We consider that the changes in the macrofaunas were mainly the result of evolution, and that the evolutionary changes are of stratigraphic significance. Alternative stratigraphic reconstructions for the southwestern part of the basin have been discussed elsewhere (see Cundill & Meyers, 1964, and Power, 1967).

The Black Alley Shale is a thin claystone sequence resting conformably or disconformably on the Peawaddy Formation. The formation contains beds of bentonitic clay, which were formed from volcanic ash laid down in an aqueous environment with restricted circulation. The presence of gypsum and jarosite on bedding planes and joints also indicates a restricted environment, which possibly developed during the transition from marine to freshwater conditions. The Black Alley Shale contains few marine macrofossils, but acritarchs are present throughout. There is a swarm of one particular species in one interval near the base. The abundance of acritarchs distinguishes the Black Alley Shale from the palynological assemblage in the overlying Blackwater Group. Some of the shale beds near the base of the formation contain a mosaic of overlapping spines on bedding surfaces which resemble molds of ice crystals. The shale was probably laid down in cold stagnant brackish water with limited access to the open sea. The presence of bentonitic clay and beds of tuff indicate contemporaneous vulcanism.

The Black Alley Shale lenses out to the northeast or is replaced by the upper part of the German Creek Coal Measures. It thickens to the southeast and east and is probably continuous beneath the Mimosa Syncline, with the upper part of the Blenheim Subgroup of the lutite province.

The upper part of the Peawaddy Formation, including the Mantuan Productus bed, grades laterally to the northeast into the basal part of the German Creek Coal Measures. The lower part of the Peawaddy Formation grades laterally into the lithologically similar Maria Formation and is probably continuous with the sediments in the northern part of the basin. The Peawaddy Formation possibly grades laterally into the lower part of the Blenheim Subgroup in the lutite province, where the Barfield Formation and lower part of the Flat Top Formation probably represent most of the Peawaddy Formation. Possibly, the Black Alley Shale was laid down in a westerly extension of the lutite province in the closing stages of deposition of the Blenheim Subgroup; the Black Alley Shale and the Flat Top Formation are lithologically similar and may be equivalent in part. The Peawaddy Formation in the northern part of the Denison Trough may include some of the oldest sediments in the Blenheim Subgroup, which may account for the near-conformity between the Catherine Sandstone and Peawaddy Formation. Presumably the basal beds of the Peawaddy Formation became progressively younger as the formation transgressed to the southwest.

Flysch(?) Province

The Oxtrack Formation extends to the north of the lutite province into the flysch(?) province where it is overlain by the Boomer Formation. The

Oxtrack Formation represents a widespread period of neritic carbonate sedimentation before major downwarping initiated the deposition of thick mudstone in the lutite province and the deposition of the Boomer Formation in the flysch(?) province. The Boomer Formation is apparently a lateral equivalent of the Barfield Formation and possibly of the Flat Top Formation also.

The Boomer Formation is the only unit recognized in the flysch(?) province. It consists of interbedded quartz-poor lithic sandstone and dark blue siltstone. The contact between siltstone and overlying sandstone beds is sharp, but there is generally a narrow transitional zone between the sandstone and overlying siltstone. In places, convolute lamination can be seen in the upper part of sandstone beds. The uniformity of thickness and lithology of individual beds over considerable distances suggests that they were deposited by turbidity currents (see Sanders, 1965). In places, the sandstone beds are very thick and are separated by thin partings of siltstone. Elsewhere, the sequence generally consists of thinly interbedded coarse and fine siltstone, although thick massive beds occur in places. Polymictic pebble conglomerate and conglomeratic mudstone are locally abundant. In some of the conglomerates, the pebbles consist mainly of fine-grained quartz-rich sandstone; in others, they consist mainly of volcanic rocks and tuffaceous sandstone. The conglomeratic mudstone contains hard, round or flattened, small to medium sized pebbles of sandstone, argillite, and tuffaceous sediments set in a sheared silty matrix; the pebbles are aligned parallel to the shear planes.

The Boomer Formation appears to be more or less conformable within the Back Creek Group west of the Broadsound Range and in the Strathmuir Synclinorium, but it unconformably overlies the basal beds of the Back Creek Group southeast of the Broadsound Range, and farther south it rests unconformably on Rannes Beds and Connors Volcanics. In the eastern part of the Gogango Overfolded Zone, the Boomer Formation rests unconformably on inliers of Silurian-Devonian rocks and is generally conformable on, or locally interfingers with, the Rookwood Volcanics. Farther east, beyond the Bowen Basin, the Boomer Formation interfingers with and is overlain by the Moah Creek Beds.

The Boomer Formation was laid down in an area where the Tiverton and Gebbie Subgroups were not deposited or where they have been subsequently removed by erosion. The area of sedimentation corresponds with the central part of the Gogango Overfolded Zone, which was strongly downwarped about the end of the Lower Permian when the submarine spilitic Rookwood Volcanics were extruded, followed by deposition of the Boomer Formation. The thickness is difficult to measure, but is estimated to be 1800 to 3000 m. The Moah Creek Beds to the east of the Boomer Formation appear to be partly younger, and pass eastwards into the coarser Dinner Creek Beds which appear to be generally younger still. At this time the area of sedimentation extended eastwards to where 'molasse' sediments were deposited adjacent to uplifted blocks of the Yarrol Basin.

The thickness and nature of the sediments suggest that they were laid down in local downwarps associated with vigorous uplift of the adjacent land. These movements culminated in middle Upper Permian time in folding, deformation, uplift, and igneous intrusion to form the Gogango Overfolded Zone.

There is an almost total absence of organic remains in the Boomer Formation. The only marine fossils are found in the most southerly outcrops, near the lutite province. Marine fossils are also rare in the Moah Creek Beds. The fossils, lithology, and stratigraphic position are the reasons for regarding the Boomer Formation as part of the Blenheim Subgroup of early Upper Permian age (in the 1:500,000 geological map of the Bowen Basin, the Boomer Formation is shown separately in the legend from the Blenheim Subgroup). The formation was presumably deposited in a marine environment, and the reason for the paucity of fossils is uncertain. Possibly the type of sedimentation, involving the rapid deposition of sheets of sediment over large areas, inhibited the development of fauna.

Lutite/Quartzose Arenite Province

The lutite/quartzose arenite province is exposed on the west flank of Connors Arch, on the northern part of the Collinsville Shelf, and around the Bundarra Granodiorite; the most southerly outcrops are about 130 km from the nearest outcrops of the Boomer Formation. The Blenheim Subgroup in the Folded Zone may be transitional between the flysch(?) province and the lutite/quartzose arenite province.

The Blenheim Subgroup in the lutite/quartzose arenite province comprises three unnamed formations. The basal unit consists of mudstone, siltstone, and silty sublabile sandstone; the sequence is conglomeratic locally near the base, and contains scattered pebbles and boulders and coquinitic beds. The Big Strophalosia Zone consists of up to 30 m of calcareous siltstone or fine sandstone; it contains abundant transported brachiopod valves, and scattered pebbles and angular blocks. The bed is apparently continuous throughout the province. The middle unit consists mainly of dark blue micaceous siltstone, and the upper of a thin sequence of quartzose sandstone. Around the Bundarra Granodiorite, the upper unit is thicker, and lenses of quartzose sandstone occur in the middle unit. Coquinitic beds, scattered marine fossils, bryozoans, and abundant evidence of reworking of the sediments by a benthonic fauna are found throughout.

The arenites contain from 75 to 90 percent quartz grains. The siltstone and mudstone contain more mica than the siltstone of the Boomer Formation and the arenites are much richer in quartz. Organic remains are common in the lutite/quartzose arenite province, but are almost completely absent in the Boomer Formation.

The maximum thickness in the lutite/quartzose arenite province is estimated at 1560 m at the southern end of the outcrop belt. A similar thickness is exposed around the Bundarra Granodiorite. The sediments were deposited below the depth of vigorous wave action in a moderately shallow sea, apparently well aerated and unrestricted. The Blenheim Subgroup conformably or disconformably overlies the Gebbie Subgroup.

Coquinite Horizons

The Big *Strophalosia* Zone is a particularly thick and extensive example of the coquinitic lenses which occur in the Back Creek Group. Other named examples are the *Streptorhyncus* bed in the Collinsville area, the *Strophalosia clarkei* bed and pelecypod bed on the Capella Block, and the Mantuan *Productus* bed in the Denison Trough and western part of the basin. All five occur in the Blenheim Subgroup. The Big *Strophalosia* Zone and the *Strophalosia clarkei* bed may be time equivalents; the Mantuan *Productus* bed may be slightly younger and equivalent to the other two. They were named because they are sufficiently distinctive and widespread to be useful in mapping. In general, all the coquinites have a matrix of calcareous siltstone or fine sandstone, and are packed with mainly separate valves of brachiopods and other fossils.

They contain scattered rounded pebbles and large angular blocks up to 60 cm across. The coquinites usually include some unfossiliferous interbeds of siltstone or sandstone similar to the coquinite matrix. The fossils are uniform in size, possibly because of sorting during transport or because of selective removal from the source area. Most of the fossils are only slightly worn and some of the strophalosids still have spines attached; this suggests that they were not transported very far.

Other coquinites in the Back Creek Group, such as in the basal formation of the Tiverton Subgroup near Homevale and farther north, are generally similar to the Big *Strophalosia* Zone. The fossils are slightly worn, the strophalosid valves, at least, are separated, and the species are mixed together, though individual species generally predominate in particular bands;

these facts suggest that the fossils have been transported a short distance. Most of these coquinites lack the uniform size sorting which is characteristic of the three named coquinites, but they do contain pebbles and scattered angular clasts.

Coquinitic beds, ranging from 15 cm thick to a maximum of 33 cm in the Big Strophalosia Bed occur throughout the Back Creek Group on the western flank of Connors Arch. Their relative stratigraphic positions can be determined accurately and, as they contain most of the species found in the Back Creek Group, they have provided most of the data on which the faunas have been subdivided into Faunas II, III, and IV. Their stratigraphic relationships and lithological similarity indicate that the faunal subdivisions reflect evolutionary development as well as environmental changes. The continuity and completeness of the faunal and stratigraphic sequence in this area permits isolated faunas from sediments of diverse depositional environments in other parts of the basin to be assigned with confidence to a particular faunal subdivision.

Paralic Province

The silty Blenheim Subgroup in the northern part of the Collinsville Shelf grades to the southwest into the sandy sequence of the paralic province. In the north the paralic sediments are exposed south of the Bowen River, but farther south they are covered by Tertiary sediments or crop out sporadically between expanses of Cainozoic alluvium. The main area of outcrop on the Capella Block, extends from near the Peak Downs Highway to east of Capella. The sequence consists of a lower unit of silty sandstone and siltstone with a basal conglomerate; it includes the Strophalosia clarkei bed near the base and a higher coquinite, the 'pelecypod bed' near the top. The S. clarkei bed is a probable time-equivalent of the Big Strophalosia Zone and may be continuous with it; it occurs nearer the base of the subgroup than the Big S. Zone, which suggests that the basal beds of the subgroup became appreciably younger as it transgressed to the west. On the Capella Block, the Blenheim Subgroup rests unconformably on pre-Permian rocks and overlaps the lower subgroups of the Back Creek Group. The lower unit was deposited in a shallow advancing sea. The abundance, in places, of large blocks in the basal conglomerate and the irregular distribution of the subgroup indicate the irregularity of the surface transgressed.

The upper unit (the 'Passage Beds' of Reid, 1924) on the Capella Block consists of cross-bedded quartzose sandstone with interbeds of siltstone and minor coal seams; it is much thicker than the lower unit. It contains plant and wood remains but no marine fossils, and was possibly deposited in fresh water. It appears to lens out to the south near Stephens Creek.

The lower unit thickens greatly at the southern margin of the Capella Block, where it is overlain by the German Creek Coal Measures and apparently grades laterally into the Maria Formation of the Comet Ridge *.

The German Creek Coal Measures were probably laid down during the same regressive phase as the 'Passage Beds' farther north, but the lateral relationships are uncertain. The German Creek Coal Measures were laid down in a marine and at times brackish delta which overlapped the silty Maria Formation. The basal beds of the coal measures appear to be lateral equivalents of the sandy upper part of the Peawaddy Formation, including the Mantuan Productus bed. The distribution of the coal measures is shown in Figure 14.

The boundary of the German Creek Coal Measures coincides with the southeast margin of the Capella Block. The southern part of the block is covered by a thin sequence of Permian sediments, comprising 60 to 90 m of the lower unit of the Blenheim Subgroup disconformably overlying equivalents(?) of the Aldebaran Sandstone near the eastern margin. In the Norwich Park 1 well, 6½ km west of the eastern edge of the block, the sequence consists of about 135 m of possible Aldebaran Sandstone below about 45 m of basal Blenheim Subgroup. This thin veneer of gently folded basal Blenheim Subgroup sediments dips east and south parallel to the regional fall of the topography. At the edge of the block the regional dip steepens slightly and the sequence thickens. The Maria Formation, which is the lateral equivalent of the basal part of the Blenheim Subgroup on the Comet Ridge, is about 245 m thick in the Cooroorah 1 well 24 km southeast of the edge of the shelf.

The palaeontological data suggests that the basal Blenheim Subgroup unit is the lateral equivalent of the complete Maria Formation. The 'pelecypod bed' at the top of the unit is considered to be a correlate of a coquinitic sandstone in the basal beds of the German Creek Coal Measures. Only a thin veneer of sediment was laid down on the Capella Block, while a much greater thickness was deposited to the east on the Comet Ridge. The style of folding on the Capella Block consists of very low-amplitude drape structures, quite different from the sinuous anticlines and synclines of slightly greater amplitude on the Comet Ridge. The thin sedimentation can be related to the relatively small subsidence of the underlying basement block which also controlled the style of folding.

* An alternative correlation is discussed in Devine & Power (1967) and Dickins & Malone (1968).

The thin basal unit of the Blenheim Subgroup extends throughout this belt of outcrop on the Capella Block. In the north the basal beds are overlain by the thick but areally restricted 'Passage Beds'. The style of folding is consistent throughout this belt which is underlain by part of the tectonically stable Clermont Stable Block. The 'Passage Beds' represent freshwater sedimentation on the block, and they may be replaced by marine sediments of the same age to the east beyond the basement block.

Comet Ridge-Folded Zone

The Maria Formation is recognized only on the Comet Ridge. Lithologically, it resembles the lower part of the Peawaddy Formation, and to some extent the lower part of the Blenheim Subgroup in the lutite/ quartzose arenite province. The arenites in the Maria Formation are mainly quartz-poor lithic sandstone, unlike those in the northern part of the basin. However, the Maria Formation is probably continuous with the Blenheim Subgroup in the north. Outcrops of the Blenheim Subgroup in the Folded Zone are mainly time equivalents of the German Creek Coal Measures. They consist of interbedded worm-tracked cross-bedded sublabile sandstone, micaceous siltstone, carbonaceous mudstone, and widespread thin sandy coquinites. The coquinites are correlated with those near the base of the German Creek Coal Measures, and are approximate correlates of the Mantuan Productus bed, the 'pelecypod bed' and the Streptorhyncus bed. The sediments resemble the upper part of the Blenheim Subgroup in the northern part of the basin, but the arenites contain a greater proportion of lithic grains. The lithic material may have come from the provenance area of the Boomer Formation. The subgroup in the Folded Zone may represent a mixture of material from the southeast, north, and west. No coal seams have been recorded, and presumably it was laid down in a shallow marine environment. The contact with the overlying Blackwater Group may be transitional.

Depositional Tectonics

The Blenheim Subgroup is the most widespread unit of the Back Creek Group, and of the entire Bowen Basin sequence. It was laid down during a major marine transgression which culminated some time after deposition of the Blenheim Subgroup began. Thereafter, the sea gradually regressed and finally withdrew or was cut off from the basin about the end of Blenheim Subgroup time.

The marine transgression was initiated by slow regional subsidence which gradually spread farther inland. In the deeper water environment in the northern part of the basin and the Denison Trough marine sedimentation was continuous or almost continuous during the late Lower Permian, and may have continued into the Upper Permian. On the stable block in the southeastern part of the basin, which was a land area of low relief during the late Lower Permian, a thin veneer of the neritic sediments (Oxtrack Formation) was now laid down. Thereafter, subsidence proceeded more rapidly in the east, and the predominance of fine-grained epineritic sediments indicates that the rate of subsidence generally kept pace with or exceeded the rate of sedimentation.

The area of major subsidence is partly indicated in Figure 14, but has been distorted by late Permian and later uplifts in the east. It probably extended much farther east across both the Connors and Auburn Arches. The sediments indicate a landmass to the east near Rockhampton. The open sea was probably connected with the northern part of the basin, north of the Rockhampton landmass. It may also have been connected with the lutite province, and extended south of the Rockhampton landmass across the Yarrol Basin. Certainly, any land bounding the lutite province was well east of the outcrop belt on the west flank of the Auburn Arch. Reconstruction of the Upper Permian palaeogeography of the basin obviously involves the areas to the east and south, and cannot be attempted at this stage.

The Rookwood Volcanics are restricted to the Gogango Overfolded Zone which was the site of maximum early Upper Permian sedimentation. The Overfolded Zone lies between the more stable Connors and Auburn Arches, and was the site of maximum subsidence followed by uplift and deformation. The igneous intrusions in the Overfolded Zone were emplaced about the middle of the Upper Permian, probably during uplift and folding. The orogeny was possibly accompanied by uplift of the Connors Arch and, to a lesser extent, of the Auburn Arch which cut off the Bowen Basin from the sea. The deposition of the Blenheim Subgroup was followed by freshwater sedimentation. The change from fossiliferous marine sediments to plant-bearing freshwater sediments is generally very sharp. In the Folded Zone, the boundary is transitional, and deposition possibly continued throughout a transition from a marine to brackish and finally to a freshwater environment. The difference in the eastern provenance areas of the Blackwater Group was probably due to uplift. In the west the provenance areas were probably not greatly different.

PERMIAN ROCK UNITS OF THE EUNGELLA-CRACOW MOBILE BELT

In the map area the Youlambie Conglomerate and Rookwood Volcanics occur only in the Eungella-Cracow Mobile Belt. The early Lower Permian Youlambie Conglomerate is part of the Yarrol Basin sequence which extends westwards into the Bowen Basin. The Rookwood Volcanics of probable early Upper Permian age rest unconformably on the Youlambie Conglomerate, and interfinger with and are overlain by the Boomer Formation. They were erupted during a period of submarine vulcanism in the strongly downwarped eastern extension of the Bowen Basin. The two formations are summarized in Table 11.

The Youlambie Conglomerate is probably a time equivalent of the Lower Permian sediments of Quail Island which are similar in gross lithology. Possibly it may be equivalent to and continuous with the upper part of the Torsdale Beds. The few fossils in the Youlambie Conglomerate indicate that it was deposited at the same time as the Carmila Beds or the lower part of the Back Creek Group, but the stratigraphic relationships between them are not known. The Youlambie Conglomerate may represent the western margin of Lower Permian marine sedimentation in the Yarrol Basin, which was separated from the Carmila Beds and Back Creek Group by a ridge of Connors Volcanics and Rannes Beds. Alternatively, the Youlambie Conglomerate may have been continuous with part of the Carmila Beds or lower part of the Back Creek Group; the connexion may be buried beneath or included in the Rannes Beds, or possibly was removed by erosion.

Uncertainty about the stratigraphic position of the Rannes Beds has hindered understanding the stratigraphy of the Gogango Overfolded Zone.

Unnamed Lower Permian

Quail Island, immediately east of Long Island, is occupied by at least 4500 m of Lower Permian siltstone containing ferruginous concretions, feldspathic sandstone, and lithic conglomerate. The sequence overlies the Neerkol Formation though the contact has not been observed. Lower Permian sediments were tentatively identified on the mainland, south of Quail Island, where they are possibly faulted against Lower Palaeozoic metamorphics (see Fig. 6).

The Lower Permian rocks of Quail Island contain a marine fauna and can probably be correlated with the Youlambie Conglomerate (see Kirkegaard et al., in prep).

Rookwood Volcanics

The Rookwood Volcanics have been defined and described by Malone et al. (1969). The formation consists mainly of spilitic pillow lavas with some agglomerate, volcanic breccia, and chert, and a little tuffaceous sandstone and siltstone. The pillow structures are well developed. The pillows range from 15 cm to 1 m in diameter and have a thin fine-grained skin and radial cracks; some have a thin vesicular layer beneath the skin. The pillow lavas grade in places into agglomerate and breccia, and in places they are silicified.

The Rookwood Volcanics are essentially massive. The contacts are not well exposed, but their regional distribution indicates that they rest unconformably on the Rannes Beds, Silurian-Devonian rocks, the Yarrol Basin sequence, and the Youlambie Conglomerate, and are overlain by, overlapped by, and interfinger with the Boomer Formation. In the Fitzroy River, the contact with the Boomer Formation appears to be conformable. In the Boomer Range, the Boomer Formation sediments are interbedded with thin flows of pillow lava resting on Silurian-Devonian rocks; elsewhere the sediments have overlapped the volcanics and directly overlie the Silurian-Devonian rocks.

The Rookwood Volcanics are intruded by a granodiorite stock, which has been isotopically dated at about 240 m.y. Near their contact the Rookwood Volcanics and the Rannes Beds are intruded by gabbroic stocks which may represent two of the vents from which the spilites were extruded.

The Rookwood Volcanics apparently consist of several thick overlapping lenses of spilitic volcanics, rather than a single extensive sheet. A thickness of more than 900 m was estimated on the southwest flank of the Craigilee Anticline, based on the dip of the underlying and overlying units, but are very thin over the inlier of Silurian-Devonian volcanics 45 km north-northeast of Duaringa where their distribution was possibly partly controlled by the topography.

The Rookwood Volcanics were possibly contemporaneous with the intrusive serpentinite near Marlborough, just north of the most northerly exposure of volcanics. The volcanics are confined to the Gogango Overfolded Zone, where strong subsidence took place in the early Upper Permian. The subsidence may have been mainly the result of faulting, and it is possible that extrusion of the Rookwood Volcanics was localized by the faults. Certainly, faulting played an important part in the emplacement of the serpentinite and in the uplift of the Marlborough Block.

BLACKWATER GROUP

The Blackwater Group was deposited in much the same trough as the Blenheim Subgroup, but apparently did not extend east into the Gogango Overfolded Zone (see Fig. 16). Maximum sedimentation was localized at the northern end of the trough where up to 2100 m of sediments were deposited. This represents a major change in the pattern of subsidence and sedimentation which prevailed during deposition of the Blenheim Subgroup. In the west, the Blackwater Group extended as far as the Blenheim Subgroup transgression, but in the north it possibly did not extend so far west.

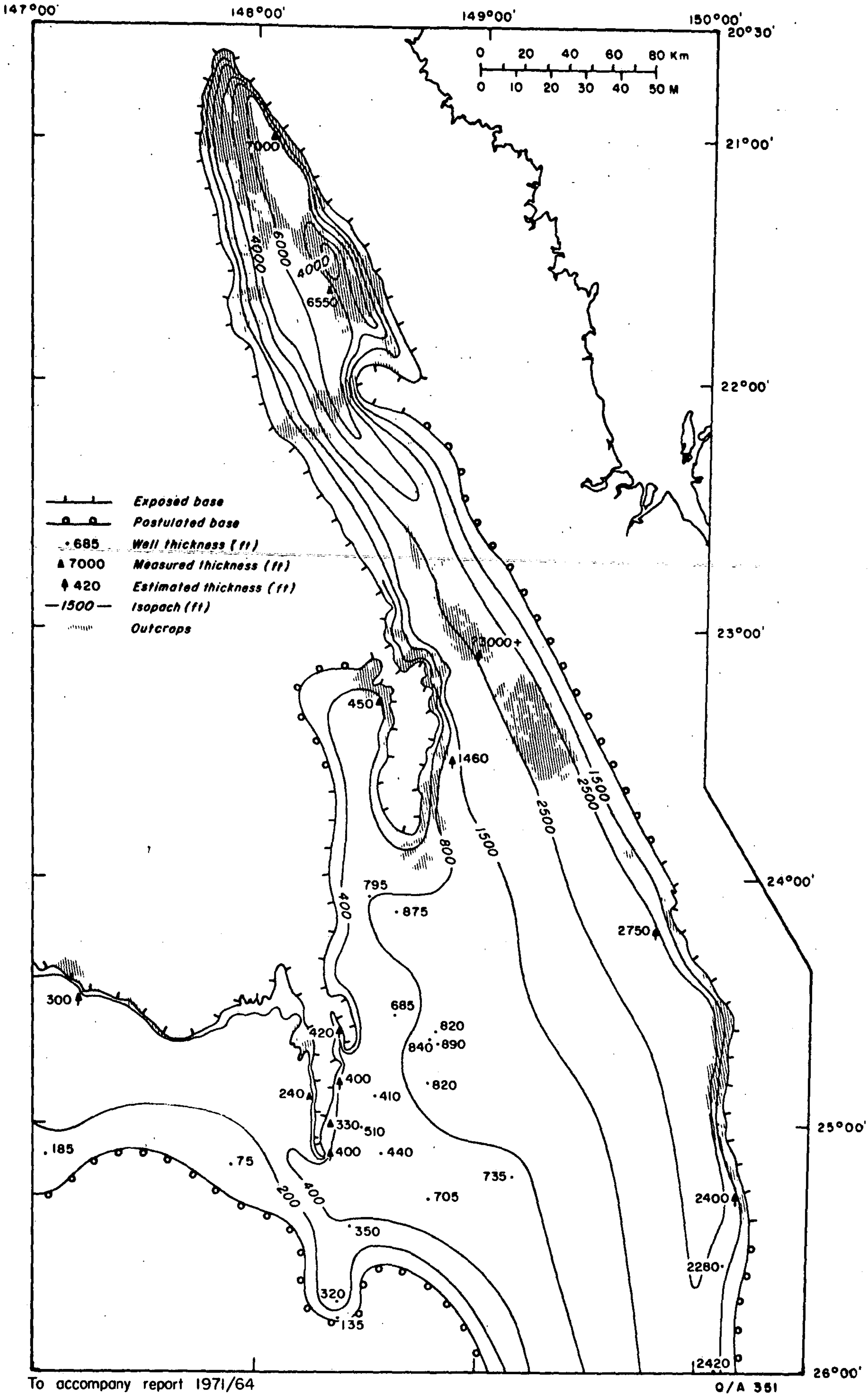
The Blackwater Group is divided into three formations on the Comet Ridge and into two formations in the Baralaba-Cracow area; elsewhere the group has not been subdivided. The stratigraphy is briefly described in Table 12. Typical well and outcrop sections, illustrating the lateral variations, are presented in Figure 17.

The Rangal Coal Measures at the top of the sequence in the type area of the group are probably widely distributed. The remaining formations of the group vary from area to area, particularly from south to north. The thick sequence in the north probably consists of thick lateral equivalents of the same formations as on the Comet Ridge, but other formations are possibly present. In both areas, the Blackwater Group is structurally conformable on the youngest part of the Blenheim Subgroup. The contact is generally sharp in the north, but in places on the Comet Ridge and in the Folded Zone nearby it appears to be transitional. There is no evidence of uplift and erosion between the Blackwater Group and Blenheim Subgroup, but there may have been a brief hiatus. The Blackwater Group is overlain by the Rewan Formation on the Comet Ridge and in the north. The contact is locally disconformable, but is generally transitional and is probably diachronous within a limited time range.

The relationships of the Blackwater Group in the Baralaba-Cracow area are similar to those on the Comet Ridge. The group is structurally conformable on the Flat Top Formation, and the contact may be transitional. The gradual reduction in the number of marine fossils towards the top of the Flat Top Formation suggests that the water became progressively fresher. The Rewan Formation appears to rest conformably on the Blackwater Group, but the presence of a thick basal pebble conglomerate suggests that they may be unconformable. The contact is too poorly exposed to determine the precise relationship. The formations in the Baralaba-Cracow area are similar to those in the type area. The Baralaba Coal Measures at the top are similar to and probably continuous with the Rangal Coal Measures. The volcanic member at the top of the Gyranda Formation is comparable with the Burngrove Formation, though it is much coarser in grain, probably because it was closer to the volcanic source. The Gyranda Formation volcanic member contains medium to coarse-grained tuffs, some of which contain biotite; the Burngrove Formation consists mainly of fine ashstone. The lower part of the Gyranda Formation differs considerably from the Fair Hill Formation, and they were probably derived from different provenance areas.

The Blackwater Group in the Denison Trough and in the western part of the basin is less than 150 m thick. It consists mainly of coal measures underlain by a thin sequence of fine to coarse conglomeratic sandstone and a thin cherty tuffaceous(?) bed containing many fossil logs. The group is disconformably or in places unconformably overlain by the Rewan Formation, and is probably disconformable on the Black Alley Shale.

The thick sequence in the north is partly illustrated in Figure 16 (near Nebo). The sequence can probably be subdivided (see Jensen, 1968). The sequence from the base upwards consists of 450 m of lithic sandstone, which is mainly calcareous and pebbly, with bands of conglomerate and interbeds of mudstone near the top. The basal sandstone is overlain by a poorly exposed sequence, about 420 m thick, which includes tuffaceous and muddy lithic sandstone and siltstone, chert, and hornblende diorite sills. The next unit is about 600 m thick. The lower part consists mainly of brown carbonaceous mudstone with thick interbeds of muddy labile sandstone and sandy limestone; the upper part is poorly exposed, and outcrops consist mainly of sandstone and limestone with thin interbeds of mudstone. The upper part of the group is about 520 m thick. It consists of calcareous pebbly labile sandstone, with conglomerate bands, sandy limestone, mudstone, carbonaceous shale, coal, cherty fine tuff, and tuffaceous sandstone. The lithology of the Blackwater Group in the type area is similar to that in the north, but the sequence is different. For example, the fine cherty tuff beds with abundant



To accompany report 1971/64

Q/A 351

Fig. 16 Distribution of the Blackwater Group

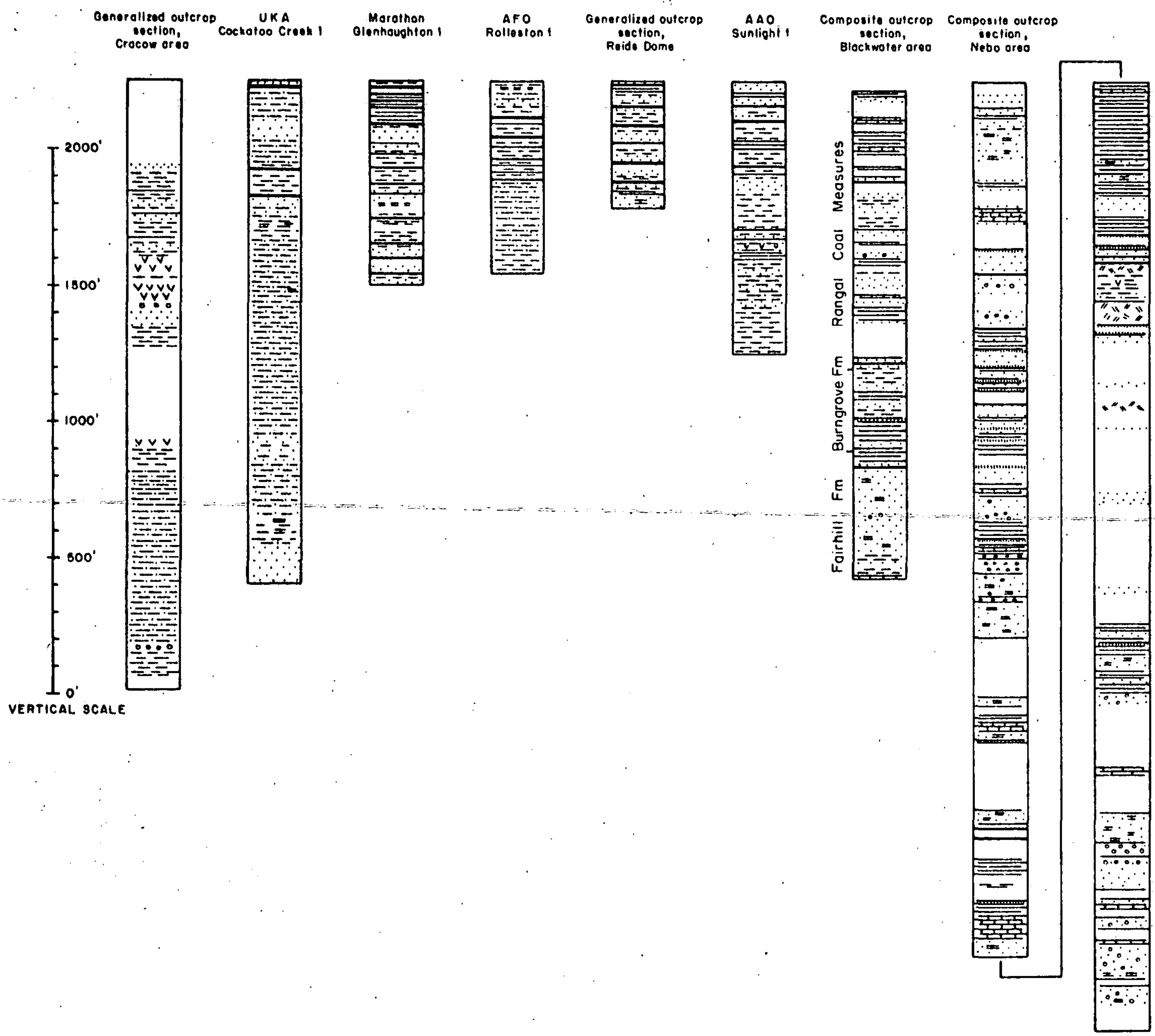


Fig. 17 SECTIONS OF THE BLACKWATER GROUP
TO ACCOMPANY RECORD 1971/64

M(S) 117

plants are generally confined to the Burngrove Formation in the type area, but in the north they occur throughout most of the group. For this reason, and because of the greatly increased thickness, it is not possible to correlate the formations in the type area with those in the north. Considerable drilling will be required to trace the formations from the type area on the Comet Ridge along the Collinsville Shelf and into the Nebo Synclinorium to the north where the thickest sequence is located.

The whole of the Blackwater Group was apparently deposited in a non-marine, mainly fluvial environment. Locally, the sediments were laid down in lakes or swamps, and towards the end of sedimentation coal measures were deposited in an extensive system of swamps and sluggish rivers. Coal is most abundant in the upper part of the group, but thin seams occur in the Burngrove Formation and local thick seams are present near the base.

Calcite is abundant in the Blackwater Group. It occurs as matrix or cement in the calcareous sandstone and siltstone, or as sandy or silty limestone. The abundance of calcite in this type of environment seems unusual. The arenites in the Blackwater Group, particularly in the north where calcite is most abundant, contain mainly plagioclase grains and fragments of volcanic rocks and were derived from a volcanic provenance area. The calcite in the sediments was probably derived from the same volcanic source, and was probably formed during diagenesis of the volcanics. The Connors Arch is considered to have been the main provenance of the Blackwater Group in the north. Some of the calcite in the Blackwater Group may have been derived from the Lower Permian and older volcanics, but some of the volcanic detritus was provided by contemporaneous vulcanism.

The Blackwater Group contains an abundant and varied fossil flora, which indicates a Permian to Lower Triassic age. The lower age limit is fixed by the early Upper Permian (Kazanian) marine fauna in the Blenheim Subgroup. The Blackwater Group is probably entirely Upper Permian. The spore assemblage in the Blackwater group is distinctly different from that in the overlying Rewan Formation, and the break may coincide with the Permian-Triassic boundary or may have taken place late in the Upper Permian.

Biotite from a tuff at the top of the Gyranda Formation has been dated isotopically at about 240 m.y. (Webb & McDougall, 1967), which is about the same age as many of the igneous intrusions farther east. This date is regarded as late Upper Permian by Webb & McDougall who suggests 235 m.y. as the geochronological age of the Permian-Triassic boundary.

Depositional Tectonics

The Bowen Basin was probably cut off from the sea by uplift of the Eungella-Cracow Mobile Belt. The amount of uplift probably increased from south to north, and the Connors Arch and Gogango Overfolded Zone rose more than the Auburn Arch. This is reflected in the changes in sedimentation from the Blenheim Subgroup to the Blackwater Group in different areas. In the north, quartz-rich moderately deep-water marine sediments, mainly lutites, are succeeded by labile freshwater sediments which include considerable conglomerate near the base. Most of the labile sediments in the Blackwater Group were probably derived from Lower Permian and older volcanics on the Connors Arch, but some of the detritus was provided by contemporaneous vulcanism. In the south, the youngest sediments of the Blenheim Subgroup were possibly deposited in a transitional environment where only slight uplift was required to complete the transition from marine to fresh water. The basal Blackwater Group sediments consist mainly of fine-grained lithic sandstone overlying a dominantly lutite sequence; the change indicates a slight rejuvenation of the provenance areas. The composition of the sediments was not greatly altered, and there was probably no major change in provenance areas. The thick sequence of the Blackwater Group in the north and the sporadic vulcanism indicate that this was the area of greatest tectonic activity. There is abundant evidence that the sediments in the north were laid down by strong fluvial currents. The structure of the Permian sequence indicates that the Connors Arch was uplifted farther than the Auburn Arch. The Back Creek and Blackwater Groups dip west off the Auburn Arch at no more then 30°; they generally dip southwest off the Connors Arch at 45° or more, but in places they are vertical or overturned. Much of the uplift took place after the Permian.

The sediments in the Gogango Overfolded Zone were probably folded and uplifted about the start of Blackwater Group time, possibly in response to the same tectonism which uplifted the Connors Arch; some uplift in the Overfolded Zone or to the east must have taken place at this time to cut off the Bowen Basin from the sea. The Blackwater Group does not extend into the Overfolded Zone. This may be due to erosion, but possibly the group was never deposited in the area. The predominant Upper Permian isotopic age of the igneous rocks intruding the Gogango Overfolded Zone and the area to the east suggests an Upper Permian age for at least one pulse of orogeny which affected the Eungella-Cracow Mobile Belt.

Most of the southern part of the Bowen Basin was the site of slow steady subsidence and accumulation of sediments. The sequences deposited east and west of the central part of the basin have been removed by erosion, except in the west where the lower part of the group is very thin. The upper coal measures are better developed, and possibly, by that time, the rate of sedimentation exceeded subsidence and extensive shallow lakes and swamps were formed.

PERMIAN PALAEONTOLOGY AND CORRELATION BASED ON MARINE INVERTEBRATES

The fossils early aroused interest: in 1845 Leichhardt (1847) found masses of coniferous wood associated with coal measures in what has now become known as the Bowen Basin, and Clarke (1862) recorded marine invertebrates. In correctly recognizing their Permian age by comparison with the Magnesian Limestone of England, Clarke was ahead of his time. Daintree (letter *in* Clarke, 1867, p. 11) reports marine fossils and the plant *Glossopteris*. Fossils were first described by Etheridge Snr (1872) from collections made by Daintree. This and subsequent descriptions of the invertebrate marine fossils as well as current work are referred to in the appendices prepared by one of us (JMD) for the Reports on the 1:250,000 Sheet areas. Work on the floras is referred to in papers by Mary E. White (macroplants) also in appendices in the Reports, and Evans (1969) (palynology).

Teichert (1951) recognized a Western Australian faunal province and eastern Australian province. The faunas from the Bowen Basin belong to the eastern Australian faunal province along with those from the rest of Queensland, New South Wales, Tasmania, and the recently described faunas from New Zealand (Waterhouse 1958, 1963a, b, c, d, 1964, 1965a, b, Waterhouse & Vella, 1965). The flora is representative of the *Glossopteris-Gangamopteris* flora.

Foraminifera, corals, blastoids, crinoids, ammonites, and ostracods, although locally abundant are on the whole poorly represented. No fusulinids, conodonts, or colonial corals have been found, and trilobites are rare. Foraminifera are represented mainly by arenaceous forms (Crespin, 1958). Crinoids are restricted to a few genera. On the other hand polyzoans, brachiopods, pelecypods, and gastropods are richly developed in numbers and species. Although these groups show closer relationship with the Western Australian province than they do with New South Wales (Dickins, in press), they show a strong indigenous eastern Australian aspect. Tracks and burrowings are common. Vertebrates are very poorly represented: fish are rare and apart from possible tracks (Malone et al., 1969) amphibians or reptiles have not been recorded. Some species of brachiopods and pelecypods attain an unusually large size.

Whatever other interpretations can be placed on the pecularities of the fauna, the absence of fusulinids and colonial corals, the limited numbers of ammonites, and the indigenous developments in other groups suggest absence of warm water and the persistence of cool water conditions at least into the Upper Permian at the end of Back Creek Group time. The more recent evidence supports Teichert's (1950, p. 207) contention that a marked amelioration in climate occurred in early Artinskian time because the only ammonites are in rocks of this age and at one locality (Homevale) are relatively abundant (Armstrong, Dear, & Runnegar, 1967).

The plants are characteristic of the Gangamopteris-Glossopteris flora with its distinctive associated microflora (Balme 1962, 1963). In the Springsure area the Gangamopteris-Glossopteris flora in the Reids Dome Beds marks a distinct floral change from the Rhacopteris flora in the underlying Joe Joe Formation (White, appendix in Mollan et al., 1969). Although it has been suggested that Gangamopteris does not occur in the Upper Permian (e.g. Plumstead, 1962, p. 113), White (appendix in Mollan et al., in prep.) has identified Gangamopteris cyclopteroides Feistmantel in the Gyranda Formation. The Gyranda Formation in a general way is equivalent in age to the Tomago and Newcastle Coal Measures of New South Wales and the evidence for its Upper Permian age seems clear. Taeniopteroid leaves have been recorded by White (appendix in Malone et al., 1969), but the Glossopteris flora does not persist above the Blackwater Group and is entirely absent from the Rewan Formation.

Palaeoecological Setting

Clastic sediments make up a large part of the Permian sequence. Limestones are rare and where present generally impure. Many of the rocks are derived from an igneous terrain and volcanic flows and pyroclastics are present. Reefs are entirely unknown and, whatever effects the clastic sedimentation may have had on their development, the factors discussed in the previous section indicate cool water conditions unsuitable to reef growth.

The basin apparently represented an unstable trough with sharp, and at times high, relief in the hinterland; deltas and swamps formed at the margins in times of slow sinking.

During the middle of the Permian the sea entered the basin; in the early stages there was perhaps a wide embayment which later became restricted to east and south. During this time coal swamps were formed around the margins. Wet conditions are indicated by swamps and remnants of rich vegetation and extensive forests. In suitable conditions prolific marine life flourished, on occasions to be killed and swept into deeper water by torrents from flood run-off or violent earth movements. At times life was inhibited by the depth of water or the floods of detritus. Volcanoes were active, killing off the animals and plants and supplying detritus to the sinking trough. Ice may have been present on the hinterland, with floating ice derived locally or from outside. By the late Permian the sea was cut off by the rising mountains on the east.

As described for Western Australia (Thomas, 1958, p. 26; Dickins, 1963, p. 25) the pelecypods are commonly associated with sandy sediments whereas brachiopods and pelecypods are associated with muds.

Faunal Subdivision and Correlation

Stratigraphical discrimination of the faunas was apparently first attempted by Whitehouse (appendix 1 in Reid, 1928, p. 286). He concluded that in the Clermont area, on the western side of the basin, older faunas of the basal Middle Bowen in the Mount Britton area and of the Yatton Limestone of the eastern side of the basin were absent. The regional survey of the basin has confirmed his conclusion. Work on the stratigraphical distribution of the faunas was carried further by Hill (1950, 1957), Campbell (1953, 1959, 1960, 1961), and Maxwell (1954).

When the regional survey was initiated palaeontological work was undertaken as an integral part of the programme.

During the first year of the survey, the faunas of the thin sequence on the west side of the basin in the Clermont area, were compared with those from the thicker sequence in the east (Dickins in Malone et al., 1964, and in Veevers et al., 1964b). Four stratigraphically discrete faunal assemblages were distinguished in the east, Faunas I, II, III, and IV, from oldest to youngest. Only Fauna IV was represented in the western part of the basin, where the sequence overlies the carboniferous rocks unconformably.

In the following year, on the basis of additional information, it became apparent that the four faunas, each corresponding to one or several fossil zones, were characteristic of four distinctive rock units, namely the upper part of the Lizzie Creek Volcanics and the Tiverton, Gebbie, and Blenheim Subgroups of the Back Creek Group.

In the ensuing work it has been found useful to develop this scheme and Fauna III has been subdivided into Faunas III A, B, and C. A somewhat unexpected result has been the applicability of the scheme to a greater or lesser extent to New South Wales (Brown, Campbell, & Crook, 1968; Dickins, 1969; Runnegar, 1967a, b) and Tasmania (Brown et al., 1968; Runnegar, 1967a, b). On the basis of Waterhouse's work, the scheme can apparently be applied also to New Zealand.

The species and genera found in each of the faunal subdivisions are discussed in the reports on the sheet areas and in Dickins et al. (1964). The accompanying chart (Table 13) shows the species identified from the various parts of the basin. The taxonomic identifications are those used in the Reports. The following have been shown separately in the chart in order that their relationship can be specially examined: the probable Fauna I of the basal part of the Stanleigh Formation of the Springsure area. The faunas of the Ingelara Formation and the Catherine Sandstone, the fauna of the probable equivalent of the Ingelara Formation of the Folded Zone, and the fauna of the Oxtrack Formation.

The progressive change in the faunas is shown very clearly in the chart and not more than one or two species, if any at all, range through the whole sequence. The very marked change between Fauna II and Fauna III is shown - of the 74 species tabulated for Fauna II, only 26 are recorded higher in the sequence. Fauna IV is marked by the incoming of many species not recorded below rather than by the absence of species from lower levels - of the 83 species recorded in Fauna IV (excepting those from the Oxtrack Formation), 38 only are recorded below. 25 species from 62 species recorded from Fauna III, however, do not extend in the Fauna IV.

The fossils are, of course, from a large number of localities, at which many rock types and environments are represented. Laterally (i.e. in lateral equivalents) the fossils are found in siltstone, sandstone, mudstone, limestone and other rock types. Vertically in the sequence the different rock types and environments are represented at different levels. This gives an assurance that the changes (which are in part evolutionary) do reflect changes with time and can be used with confidence for time-correlation within the basin. Indeed the identification of these assemblages in areas outside the basin not only confirms this conclusion but shows they are valid for time-correlation, for the greater part, throughout eastern Australia and New Zealand (for application to other parts of eastern Australia see Runnegar, 1967a).

Although only a few species distinguish Fauna I from Fauna II and its merit outside the basin seems doubtful, it does seem to have some value in distinguishing the earliest marine horizons within the Bowen Basin. The recognition of Fauna I in the lower part of the Stanleigh Formation is dependent on the slim evidence provided by the presence of an Aviculopecten with unspecialized ribbing. 'Megadesmus' cf. antiquatus, referred by Runnegar (1967b) to Pyramus concentricus? is now apparently known also from Fauna II at Homevale (B. Runnegar, pers. comm.). The identification, however, of Fauna I in the Stanleigh Formation fits the other geological evidence that the earliest part of the marine sequence in the Springsure area was coeval with the final phases of the volcanic activity of the Lizzie Creek Volcanics.

The time relationship between the Ingelara Formation, Catherine Sandstone, and Oxtrack Formation poses a more complex problem especially as both the Catherine Sandstone and Oxtrack Formation contain a relatively small fauna. This is considered in detail elsewhere (Dickins, in Mollan et al., 1969; in Mollan et al., in prep.). The comparison of the faunas of the Ingelara and Peawaddy Formations from the Springsure area is particularly important. The two formations are similar in lithology and a similar association of fossils is found. Detailed examination shows, however, that a number of species do not occur in common. Species which are found, in both, however can be put aside when a faunal comparison of formations is being made. For example in discussing the relative age of the Barfield Formation, which overlies the Oxtrack Formation, the similar rock type and environment to that of the Ingelara and Peawaddy Formations is reflected in a similar faunal association and a number of species are found in common. The species which do not occur in common are therefore of consequence in determining the time relationships. Here it seems sufficiently clear from Table 13 that the Oxtrack Formation (and Barfield Formation) contain species that elsewhere are not older than Fauna IV, and that the Catherine Sandstone (and the Ingelara Formation) contain species not elsewhere restricted to Fauna IV.

One difficulty in correlating the Ingelara Formation with the sequence in the northern part of the basin has been the predominance of the brachiopods in the Ingelara Formation, in contrast to the predominance of the molluscs in the north. Important information on this question is afforded by the localities in the Folded Zone regarded as the Ingelara Formation equivalent. Here Ingelara Formation brachiopods are associated with Fauna III molluscs giving an indication that the Ingelara Formation fauna is a Fauna III and that the Ingelara Formation for example is older than the Oxtrack Formation and other formations of the Blenheim Subgroup which contain a Fauna IV (Dickins, in Mollan et al., 1969).

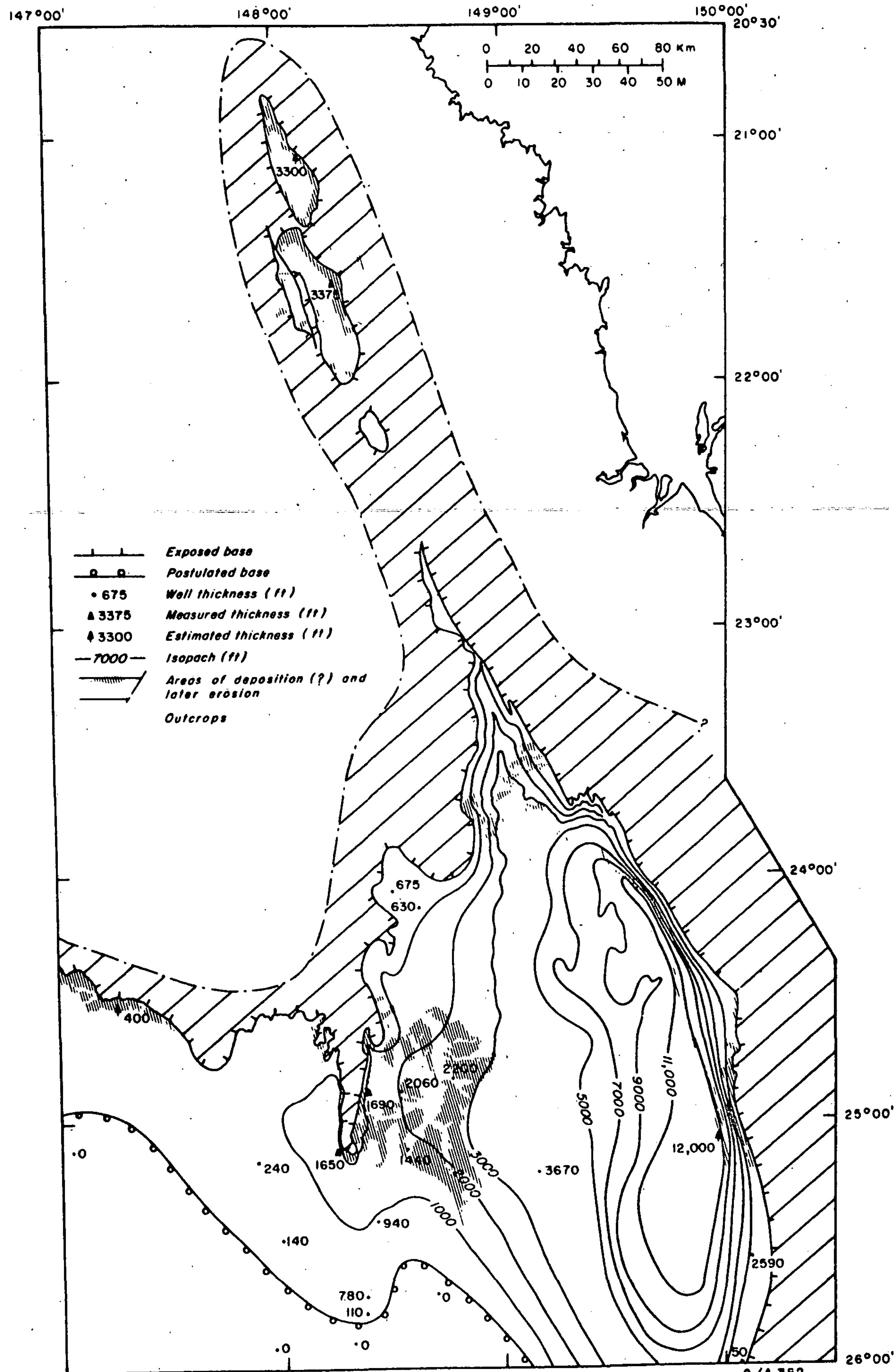
MIMOSA GROUP

The Mimosa Group consists of the Rewan Formation, Clematis Sandstone, and Moolayember Formation (see Table 14; Figs 18, 19, 20). The three formations constitute a lithogenetic unit of group rank. In most places the contacts are conformable, and where the sequence is well developed they are generally transitional. They were laid down in much the same depositional area and in similar environments. The group consists of a thick pile of mudstone and labile clastics with the quartzose Clematis Sandstone in the middle. The Mimosa Group has been separated from the Blackwater Group because (i) the marked shift in the locus of maximum sedimentation and vigorous uplift of provenance areas to the southeast indicate a major change in the tectonic regime; (ii) the abundance of carbonaceous matter and plants in the Blackwater Group and their comparative rarity in the Mimosa Group represents a major change in the environment or climate, or both; and (iii) because of the marked difference in gross lithology.

Rewan Formation

The Rewan Formation was laid down about the end of the Upper Permain mainly as the result of renewed tectonism, accompanied by a shift in the focus of tectonic activity from the northeast to southeast.

The distribution of the Rewan Formation (Fig. 18) reveals a major shift in the locus of maximum sedimentation. The trough along the eastern side of the basin is preserved, but maximum subsidence and sedimentation took place at the southern end. The type of sediments laid down indicates vigorous uplift in the southeast and south. In the southeast, the basal part of the Rewan Formation contains beds of tuff and volcanolithic pebble conglomerate, and fragments of volcanic rocks predominate in the arenites. Quartz grains form only 5 to 10 percent of the arenites in the lower part of the formation in the southeast, but constitute up to 50 percent of the rocks near the top. These changes reflect a gradual decrease in tectonic activity and vulcanism. Several igneous intrusions to the east of the Auburn Arch have been dated isotopically at about 220 m.y. (possibly late Lower Triassic to Middle Triassic), and they may have been emplaced about the same time as the Mimosa Group was laid down. As in the case of the mid-Upper Permian orogeny, the isotopic ages suggest that the intrusions crystallized after uplift and sedimentation had begun.

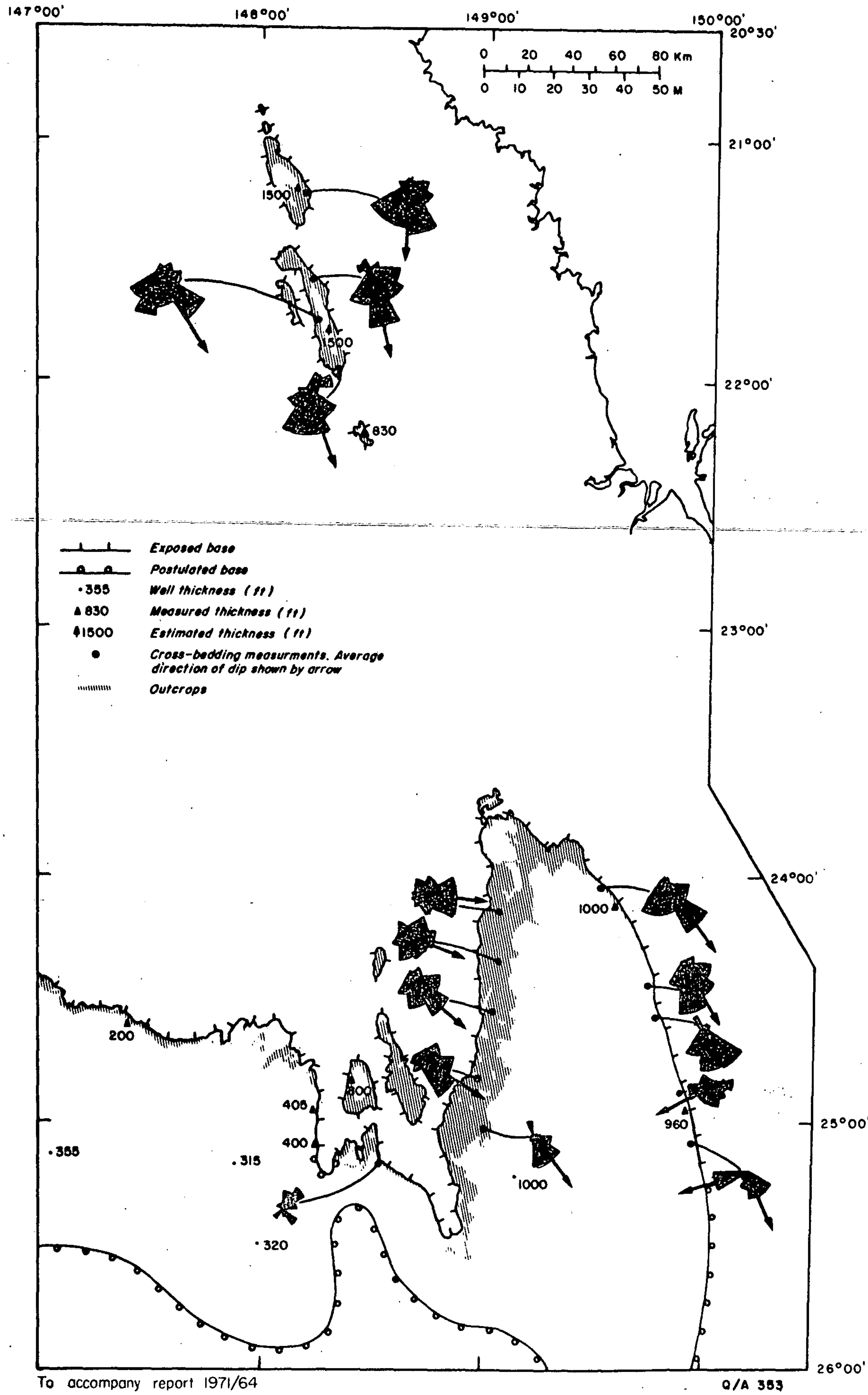


To accompany report 1971/64

Q/A 352

DISTRIBUTION OF THE REWAN FORMATION

Fig 18

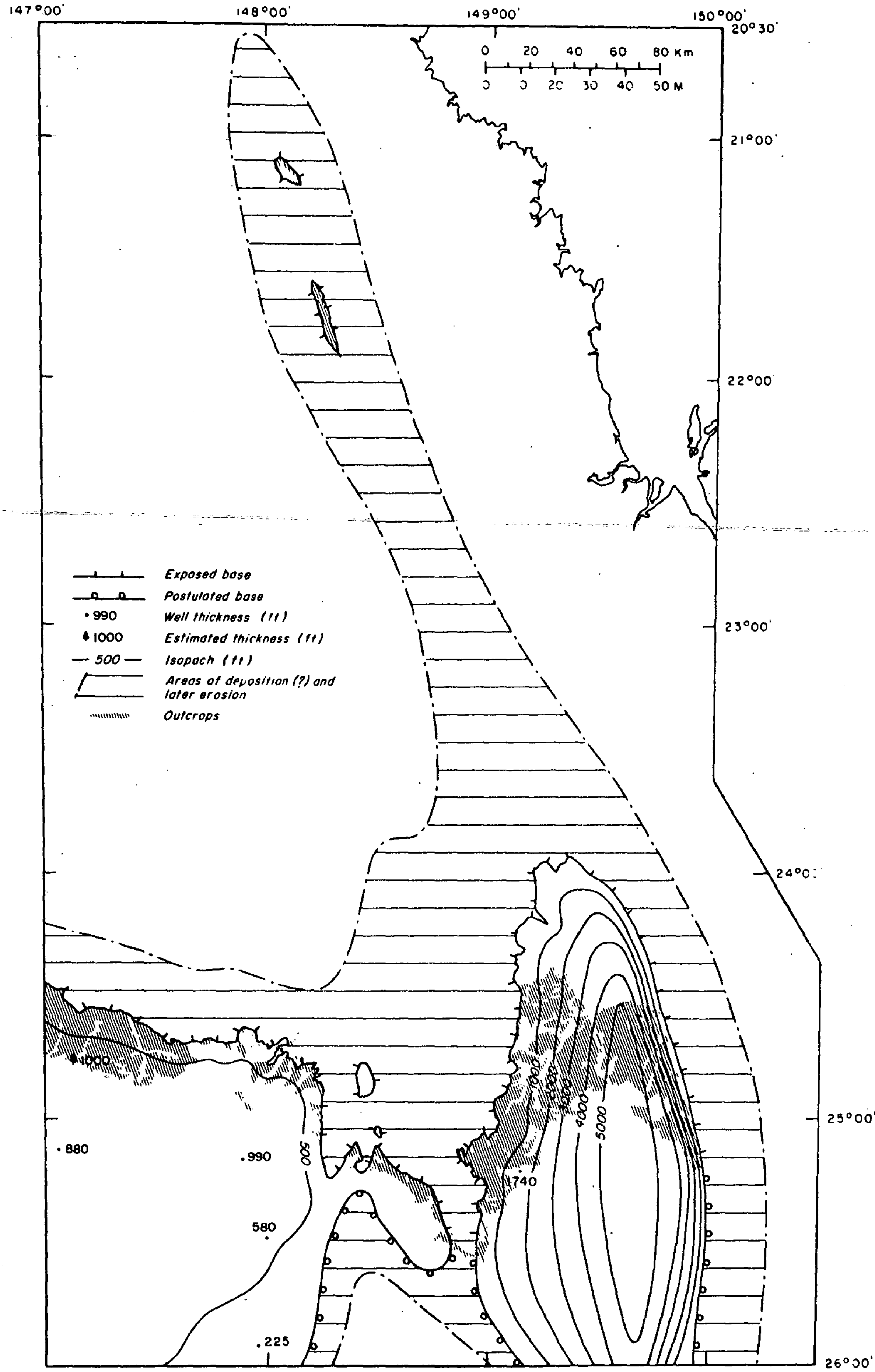


To accompany report 1971/64

Q/A 353

DISTRIBUTION OF THE CLEMATIS SANDSTONE

Fig.19



To accompany report 1971/64

Q/A 354

Fig. 20

Distribution of the Moolayember Formation

Seismic surveys across the Mimosa Syncline (Marathon, 1963) indicate that the greatest thickness of the Rewan Formation is on the east side of the Mimosa Syncline. The asymmetry of the Rewan Formation (see Fig. 18) is probably largely the result of post-depositional movements, although it was probably a depositional feature in part; presumably the depositional area extended slightly farther east on to the Auburn Arch.

The Rewan Formation is much thinner to the west of the Mimosa Sxncline and consists mainly of mudstone and fine sandstone, with some coarse and pebbly sandstone near the base. The arenites in the west contain more quartz than those in the Mimosa Syncline, but exhibit a similar increase in quartz content upwards. They contain a large proportion of volcanic detritus, though less contemporaneous volcanic material than in the southeast; they consist mainly of volcanolithic labile to sublabile sandstone.

A prominent pebbly coarse lithic sandstone, the Brumby Sandstone Member, occurs near the base of the Rewan Formation west of the Mimosa Syncline. The member forms the base of the formation in places, but elsewhere overlies a thin basal sequence with slight angular unconformity. The western provenance area was apparently slightly rejuvenated, and the basal sequence of the Rewan Formation was tilted and eroded before the Brumby Sandstone Member was laid down. The presence of recycled Carboniferous spores (Evans, 1966c) in samples from low in the Rewan Formation also suggests rejuvenation of the western provenance area.

North of the Mimosa Syncline, near Blackwater, and in the northern part of the basin, the contact between the Rewan Formation and Blackwater Group is locally disconformable and sharp, but apparently is more commonly transitional. Near Blackwater the basal sequence consists of lithic sandstone and siltstone known as the Sagittarius Sandstone Member. The red-brown mudstone, which is so characteristic of the Rewan Formation in the south, is predominant only in the upper part of the formation in the north. The Sagittarius Sandstone Member and its equivalents farther north can be distinguished from the Blackwater Group by the absence of plant remains, coal seams, and carbonaceous matter. In the north, careful examination is required to separate the topmost 30 m of the Blackwater Group, above the highest coal seam, from the overlying Rewan Formation. In the south, the boundary is quite sharp and probably disconformable, and is defined by the presence of red-brown and green mudstone near the base of the Rewan Formation. In places, in the southwest, the Rewan Formation rests with angular unconformity on the Blackwater Group.

The Rewan Formation contains a great volume of red-brown mudstone which is not found in significant amounts in the underlying formations. The mudstone contains disseminated iron oxide as very fine red-brown spots and filaments, which were probably deposited contemporaneously with the clay particles (Bastian, 1965). Because of the presence of ferric oxide, deposition in an oxidizing environment has been suggested but this alone does not explain the abundance of ferruginous clay. The green mudstone, which is also quite common, possibly contains ferrous iron.

The presence of desiccation cracks in the mudstone indicates intermittent drying up of the lakes in which the mudstone was deposited, and the ferric iron may have been produced by surface oxidation. However, as the red-brown mudstone occurs in massive unbedded units up to 30 m thick with no trace of desiccated surfaces, it was presumably deposited under water. The thickness of the beds suggests that they were not deposited in very shallow water. Possibly the red-brown mudstone is the result of an abundant supply of clay particles spotted with disseminated ferric oxide and the lack of carbonaceous material which could have led to the reduction of the iron. A change in climate is the most likely cause of the abundance of ferruginous clay, which was possibly formed as lateritic soil. The abundance of red-beds of this age in eastern Australia, and in fact throughout the world, suggest that the controlling factors operated on a continental or world-wide scale and this would be compatible with a climatological control. Most of the arenites in the Rewan Formation are trough cross-stratified, and they were probably laid down in an environment similar to that of much of the Blackwater Group. This also suggests that the change from the carbonaceous sediments of the Blackwater Group to the non-carbonaceous, oxidized(?) red-beds of the Rewan Formation reflects a general factor not confined to the area of deposition.

Clematis Sandstone

The Clematis Sandstone succeeded the Rewan Formation during a period when there was a temporary reduction in the intensity of tectonic activity. The increase in the ratio of quartz grains to fragments of volcanic rock towards the top of the Rewan Formation in the southeast indicates the slackening of extrusive activity, but not its end. The Clematis Sandstone in the southeast contains a significant proportion of volcanic detritus and generally consists of volcanolithic sublabile sandstone rather than quartzose sandstone; elsewhere quartzose sandstone is predominant and the sublabile sandstone was derived mainly from a metamorphic provenance area. The

Clematis Sandstone is much more uniformly distributed than the Rewan Formation. The thickness ranges from about 100 m in the west to 300 m in the Mimosa Syncline, and to a maximum of 450 m in the north (see Fig. 19). The distribution of the formation indicates that the Mimosa Syncline was not subsiding as rapidly as during deposition of the Rewan Formation. The slower rate of subsidence and burial of sediment could explain the greater mineralogical maturity of the Clematis Sandstone, which is mainly quartzose to sublabile. The sediments were derived from much the same provenance areas as the Rewan Formation, but were possibly subjected to considerably more chemical weathering and reworking in the fluvial environment because of the slower rate of subsidence. Mechanical reworking was not severe, however, as most of the quartz grains are of low sphericity. Most of the Clematis Sandstone consists of planar cross-bedded sandstone, probably deposited in braided river channels. The interbeds of grey and white flaggy siltstone probably represent deposition on short-lived flood-plains. Thin beds of red-brown mudstone and bands of red and yellow ochre occur between sets of cross-bedded sandstone in places; the mudstone is identical with that in the Rewan Formation.

Measurements of the cross-bedding azimuths are presented on Figure 19. The Clermont Stable Block and the Connors Arch supplied sediment to the northern part of the basin. The sediment was transported southwards along the length of the basin, probably by a series of braided river channels. The sediments are generally coarser in grain than farther south, and consist almost exclusively of cross-bedded sandstone. These sediments were originally called the Carborough Sandstone (see Malone et al., 1964, 1966). They crop out about 160 km from the nearest outcrop of Clematis Sandstone, but are lithologically similar to the Clematis Sandstone and occupy a similar stratigraphic position. The cross-bedding measurements also suggest that the Carborough Sandstone was laid down at the northern end of the Clematis Sandstone depositional area, and that the two formations were originally continuous. For this reason, the name Carborough Sandstone was regarded as a synonym of Clematis Sandstone and was abandoned.

The cross-bedding azimuths on the west limb of the Mimosa Syncline indicate that much of the detritus was derived from the southern end of the Clermont Stable Block. Measurements at the most southerly site reveal a northeasterly component, away from the southern block of pre-Clematis rocks outlined on Figure 19. Measurements on the eastern limb mainly indicate transport in a south to southeasterly direction, which suggests that the eastern margin of sedimentation probably extended farther east on to the Auburn Arch. In the south there is a strong westerly direction of transport. The sediments here contain the highest proportion of volcanic detritus, which was presumably derived from an easterly provenance area. The presence of beds of conglomerate in the Clematis Sandstone in the south suggests that the source area may have been fairly close.

The effects of the eastern volcanic provenance were probably limited to the relatively small area where volcanic detritus is present in significant amounts in the Clematis Sandstone. Even in this area, a south-southeasterly direction of transport is recognizable.

In the north, the Clematis Sandstone was probably laid down in the braided channels of a major river system flowing south along the length of the Bowen Basin. In the west the formation may have been deposited in a tributary river system, but the presence of more fine sandstone and siltstone, which were possibly deposited on flood-plains, suggests that the environment was different from that in the north. The section of the Clematis Sandstone in the Glenhaughton 1 well shows that finer sediments are also abundant in the southern part of the Mimosa Syncline. Possibly the palaeoslopes were gentler in the south, so that the braided channel type of deposition in the north was succeeded by a more normal fluvial environment of river-channel and flood-plain deposition.

Moolayember Formation

The Moolayember Formation transitionally succeeded the Clematis Sandstone with a progressive increase in the proportion of labile constituents and the reappearance of calcite in significant amounts in the arenites and to a lesser extent in the lutites. Calcite is abundant in the Blackwater Group arenites and is present in many of the coarse and pebbly arenites of the Rewan Formation, such as the Brumby Sandstone Member, but is absent in the Clematis Sandstone. The calcite commonly replaces feldspar grains and fragments of volcanic rock, but does not replace or encrust the quartz grains. The absence of calcite in the Clematis Sandstone may be related to the paucity of volcanic detritus.

The abundance of trough and planar cross-stratified labile arenites in the Moolayember Formation suggests deposition in a partly fluvial environment which differed from that of the Clematis Sandstone in that rate of subsidence was greater and the sediments were buried with considerably less reworking. The presence of thick beds of polymictic, mainly volcanolithic, pebble and cobble conglomerate in the Moolayember Formation, particularly in the east limb of the Mimosa Syncline, testifies to renewed uplift of the southeastern provenance areas. The Moolayember Formation (Fig. 20) is very thick along the axis of the Mimosa Syncline and thins rapidly to the west in contrast with the relatively uniform distribution of the Clematis Sandstone. The distribution of the Moolayember Formation resembles that of the Rewan Formation though the locus of maximum sedimentation is farther west. The Rewan Formation was laid down during a period of vigorous uplift, intrusion, and vulcanism to the east or southeast of the basin, associated with linear subsidence in the Mimosa Syncline. The intensity of tectonism waned considerably in Clematis Sandstone time and was renewed during deposition of the Moolayember Formation. The last pulse of tectonism was less vigorous than that during the deposition of the Rewan Formation and represents the final tectonic activity in the Mimosa Syncline. The syncline is the only area of considerable subsidence within the Bowen Basin which has not been subsequently uplifted or folded, and substantially the Moolayember Formation in the syncline has not been disturbed since it was deposited.

The Moolayember Formation is generally finer in grain to the west and north; conglomerate and coarse arenite are confined to the east limb of the Mimosa Syncline. Quartz is more abundant in the west but this may be partly due to the finer grainsize. The Moolayember Formation contains a large proportion of yellow-green swollen and leached biotite, which is rare in the Clematis Sandstone in the southeast. The most likely source of the biotite is the granodiorite and other plutonic rocks of the Urannah Complex and other plutonic rocks to the east of the Auburn Arch. Biotite and its alteration products are abundant in the west limb of the Mimosa Syncline and for some distance farther west, but are less common in the west. West of the syncline, the formation contains less volcanic detritus and more fragments of sedimentary and metamorphic rocks; this reflects the distance from the eastern provenance area and the supply of material from provenances to the northwest and southwest (Bastian, 1965c).

The mudstone in the Moolayember Formation commonly contains plants and carbonaceous debris and locally grades into carbonaceous shale; thin coal seams occur in places. The red-brown mudstone of the Rewan Formation and Clematis Sandstone is absent. The presence of carbonaceous matter and the absence of the red-brown mudstone indicate that the Moolayember Formation was deposited in a reducing environment without large supplies of clay particles with adsorbed ferric ions. The fine grainsize and regular bedding of parts of the formation suggest that they were laid down in lakes, and the abundance of cross-bedding indicates the importance of traction currents, probably fluvial. The Moolayember Formation was probably laid down in a fluviolacustrine environment. The presence of acritarchs (Evans, 1964a), which possibly indicate brackish or marine conditions, in the formation possibly indicates occasional incursions of the sea.

Age of the Mimosa Group

The macroflora in the Moolayember Formation and Clematis Sandstone indicates a Triassic to Lower Jurassic age. The abundant microflora has been studied more closely, and provides an effective means of determining relative ages of the formations in the Upper Permian and Mesozoic sequence, including the Mimosa Group. However, the correlation between the microfloral units and the geological time scale is uncertain, and in particular, the position of the Permian-Triassic boundary is unknown (see Evans, 1964a). In practice, in the Bowen Basin the sharp break between the microfloral assemblages in the top unit of the Blackwater Group and in the Rewan Formation is regarded as marking the Permian-Triassic boundary. A similar microfloral change is associated with the boundary between the Newcastle Coal Measures and the overlying Narrabeen Group which is accepted as the Permian-Triassic boundary in the Sydney Basin. No representatives of the Glossopteris flora are known above this horizon in either basin, but a thick florally barren sequence separates this horizon from the oldest sediments containing the Dicroidium flora. The Permian-Triassic boundary could lie within the barren sequence, that is within the Rewan Formation in the Bowen Basin, but can be no lower if the Glossopteris flora is accepted as diagnostic of the Permian. Referring to correlation with Western Australia, Evans (1964a) points out that the basal part of the Rewan Formation could be Upper Permian, but this is as yet unproved. The bulk of the formation is Lower Triassic.

The boundary between the Lower Triassic and the Middle Triassic is also uncertain. In the Sydney Basin, the Dicroidium flora becomes well established in what is regarded as a late Lower or early Middle Triassic formation. An appreciable microfloral change accompanies the establishment of the macroflora and this microfloral change is regarded as approximately marking the Lower Triassic to Middle Triassic boundary. In the Bowen Basin, this change comes above the base of the Clematis Sandstone. Its position cannot be determined because of poor preservation of spores in this formation. This implies that the Rewan Formation is no younger than the Lower Triassic and that the Clematis Sandstone extends from Lower Triassic to Middle Triassic.

The Middle Triassic to Upper Triassic boundary cannot be recognized and the Moolayember Formation is regarded as Middle to Upper(?) Triassic in age. The upper limit on the age of the Moolayember Formation is set by the angular and erosional unconformity separating it from the overlying Lower Jurassic Precipice Sandstone (Evans, 1964c).

Relationships of the Mimosa Group

The Mimosa Group consists of a generally conformable sequence of formations with transitional boundaries on the east limb of the Mimosa Syncline where the group is best developed. Farther west and southwest, where the peripheral sediments are preserved, the sequence includes unconformities, disconformities, and overlaps. The angular unconformity above the basal part of the Rewan Formation in the Arcadia area has been mentioned. In the west the Clematis Sandstone overlaps the Rewan Formation and rests directly on the Blackwater Group. The overlap straddles the trend of the Nogoa Anticline in the pre-Permian rocks, but it is not known whether the Rewan Formation was deposited in the area, or whether it has been removed by erosion. Subsurface data, mainly from south of the map area, reveal many areas on the west flank of the basin where the Rewan Formation is truncated beneath or is overlapped by the Clematis Sandstone. This situation is less common on the east limb of the basin where the sequence is thicker. However, seismic data across the anticline on which the Wandoan 1 well was drilled suggest that the Rewan Formation is truncated beneath the Clematis Sandstone across the crest of the structure (Bastian & Arman, 1965). This fold apparently began to grow and to be eroded before deposition of the Clematis Sandstone, but also continued to grow afterwards and affected both the Clematis Sandstone and Moolayember Formation.

The Clematis Sandstone penetrated in wells drilled to the south of the map area consists mainly of lutites with only a small proportion of sandstone. Possibly, this area was occupied by lakes into which flowed the rivers transporting the Clematis Sandstone. Whether these lakes occupied an internal drainage basin or whether they were connected to the sea is not known.

The Mimosa Group was truncated by erosion prior to deposition of the Precipice Sandstone at the base of the Great Artesian Basin sequence. This unconformity is best displayed in the southeast, where it truncates the entire Bowen Basin sequence from the Moolayember Formation to the Camboon Andesite and pre-Permian rocks in the east. Erosion of the Precipice Sandstone has exhumed a regolith which developed on the Bowen Basin sequence during the peneplanation preceding the deposition of the Precipice Sandstone. The mesas capped by the regolith can be easily mistaken for outliers of Precipice Sandstone. The regolith consists of a siliceous weathering profile which dips gently to the southwest, parallel to the regional dip of the Precipice Sandstone, and truncates the more steeply dipping Permian-Triassic rocks. The pre-Jurassic peneplain was reduced to a remarkably plane surface considering the differences in resistance to weathering of the Permian-Triassic rocks.

In the Denison Trough and west of the Mimosa Syncliine, the unconformity is an obvious regional angular unconformity; the Precipice Sandstone is not in contact with as many older units and the fossil weathering profile has not been preserved. Farther west, in the western part of the basin, which is occupied by a gently southerly dipping sequence, there is no angular discordance and the boundary is disconformable. This reflects the tectonic stability of the Clermont Stable Block which underlies this part of the basin.

GREAT ARTESIAN BASIN SEQUENCE

Deposition of the Great Artesian Basin sequence began in the early Lower Jurassic after a brief late-Triassic episode of uplift, minor folding, and widespread erosion and peneplanation of the pre-Jurassic rocks. The unconformity at the base of the sequence ranges from a marked angular erosional unconformity in the east to a structurally conformable disconformity in the west (see above).

The Great Artesian Basin developed as a broad regional downwarp of epi-continental proportions. Its growth marks the change from the Palaeozoic to Triassic tectonic regime or linear geosynclinal sedimentation and deformation to a regime of platform tectonics. The linear geosynclinal tectonic regime migrated east and continued to affect the northern and northeastern parts of the Bowen Basin at least until the Cretaceous.

The Great Artesian Basin consisted of a number of sub-basins which differed in sedimentation and depositional history. One of these is the Surat Basin which overlapped the southern end of the Bowen Basin and originally extended farther north than the present erosional margin of the Great Artesian Basin sequence. The Surat Basin downwarp overlapped a number of older elongate tectonic units, but the sequence in the Great Artesian Basin shows only very limited effects of the older tectonic units. These include thicker sedimentation over depositional downwarps such as the Mimosa Syncline, thinner sedimentation over basement features such as the Comet Ridge, and drape structures over older anticlines. Most of these are the result of different rates of compaction of the underlying sediments and generally reflect variations in thickness of the underlying unmetamorphosed sediments.

The Great Artesian Basin sequence is mainly confined to the southern part of the map area. It is most fully represented in the southwest corner, where the Roma Formation is exposed. The sequence in the Eddystone Taroom, and Mundubbera Sheet areas is described in Mollan et al. (in press). To the north the sequences in the Springsure and Baralaba Sheet areas are described by Mollan et al. (1969) and Olgers, Webb, Smit & Coxhead (1966). An outlier of Precipice Sandstone in the Duaringa Sheet area is described in Malone et al. (1969).

The only marine fossils in the Great Artesian Basin sequence are found in the Roma Formation. The remainder of the sequence was deposited in a fresh water, with occasional brief incursions by the sea. The microfloral assemblages have been subdivided into a number of palyno-biostratigraphic zones (Evans, 1965, 1966a) which are used for local correlation and for determining the approximate position of the rock units in the geological time scale.

Further mapping and palynological studies since the Bowen Basin map went to press have resulted in some modification and refinement of the Jurassic-Cretaceous stratigraphy as presented on the map. Part of the revised stratigraphy is presented in Mollan et al. (in prep.). According to the revised stratigraphy the sequence shown on the map about 40 km southwest of Injune as Orallo Formation belongs to the Southlands Formation. The Blythesdale Formation in the same area is represented by only the Claravale Sandstone Member. The Southlands Formation is a lateral equivalent of the Orallo Formation plus the basal members of the Blythesdale Formation in the Roma area. The Claravale Sandstone Member is a local member within the Blythesdale Formation and is at the top of the Great Artesian Basin sequence southwest of Injune.

The stratigraphy of the Roma Formation has been revised by Vine, Day, Milligan, Casey, Galloway, & Exon (1967). The changes include the introduction the name Wallumbilla Formation for the part of the sequence in the map area.

The bulk of the Great Artesian Basin sequence consists of sandstone and mudstone with minor conglomerate in places. The sequence can generally be subdivided locally into a succession of predominantly sandstone or mudstone units, but these units cannot generally be traced far because of lateral variation. In practice, only units of group rank and some of the thicker and more distinctive formations can be traced throughout the map area. Most of the formations within the groups are generally only of local extent. The stratigraphic interval represented by a particular formation in one area may fall within or may overlap the formation boundaries in an adjacent area. The relationship between the Southlands Formation southwest of Injune and the Orallo and Blythesdale Formations in the Roma area is a typical example.

Some lateral variations within the sequence apparently take place over a short distance. A sequence of formations or members will be consistent along strike lengths of 150 km or more and then will be replaced by a different sequence over 15 to 30 km. The entire sequence crops out poorly; the transition zones are not fully exposed but appear to be located on anticlinal trends related to major structures in the pre-Jurassic rocks. The Maranoa Anticline is a sinuous southerly plunging anticlinal nose of low amplitude along the course of the upper Maranoa River. The structure in the Jurassic-Cretaceous sequence overlies the buried Nebine Ridge, which is the southerly extension of the Clermont Stable Block. The Maranoa Anticline can be traced southwards beyond the map area to where it forms an axis separating the depositional basins of the Hooray Sandstone to the west from its lateral equivalents, the Gubberamunda Sandstone, Southlands Formation, and Blythesdale Formation to the east.

Other lateral changes take place gradually over great distances. A good example is the gradual increase of the thickness of the Boxvale Sandstone Member compared with the total thickness of the Evergreen Formation. The member tongues out to the east in the trough of the Mimosa Syncline and in the northwest it constitutes the entire formation.

Structure

The rock units of the Great Artesian Basin sequence are described in Table 15. The entire sequence is generally structurally conformable.

The sequence is only very gently folded or not folded at all. Most of the folds are compactional or drape structures, although some of them may have grown in Jurassic or Cretaceous times as a result of renewed movement on faults in the pre-Jurassic rocks. One of the main structures is the Mimosa Syncline in the east, in which the tectonic dips on the limbs are usually about 2°. The syncline possibly developed as a depositional structure due to compaction of the underlying great thickness of Permian-Triassic sediments.

The anticline plunging gently to the southeast to the west of the Mimosa Syncline is on strike with the Arcadia Anticline. It is defined by inliers of Precipice Sandstone in the Evergreen Formation and by a southeasterly deflection of the formation boundaries. The Hutton Creek Dome farther to the west is part of an anticlinal trend extending southeast and south, adjacent to the northern end of the Hutton-Wallumbilla Fault Zone; movement on this fault zone has apparently faulted Boxvale Sandstone against Precipice Sandstone.

The southerly plunging Merivale Syncline is located farther west, on the western side of the Merivale Fault. A monocline dipping west at 5° to 10° was probably formed as a result of slight movement on the Merivale Fault during the Jurassic. The structures farther west still include the southwesterly plunging Maranoa Anticline, and a sinuous anticlinal axis to the east. The flank dips on the anticlines are up to 5°. The presence of an inlier of pre-Jurassic rocks on the axis of the Maranoa Anticline indicates post-Jurassic uplift on this axis. These structures overlie the Nebine Ridge, which is possibly a southerly extension of the Clermont Stable Block. The west-southwesterly trending Chesterton Syncline, near the western margin of the map area, is a depositional syncline between the Nebine Ridge to the east and the Birkhead Ridge to the west. The Birkhead Ridge is a basement ridge extending southwest from the southwest corner of the Clermont Stable Block; it is the locus of thin Jurassic-Cretaceous sedimentation. Most of the Lower Jurassic units of the Surat Basin lens out or lose their identity across the Birkhead Ridge. The Hutton Sandstone and younger units extend across the ridge.

The thicker sedimentation in the synclines is largely due to a faster rate of subsidence in the synclines which overlie thicker piles of pre-Jurassic sediments than those beneath the anticlines. Some of the broad anticlinal zones of thin sedimentation are probably drape structures over basement features such as the Nebine Ridge and, near Injune, the southern end of the Comet Ridge. Other anticlines, such as the Maranoa Anticline and the Hutton Creek Dome, have been actively uplifted, and possibly some were occasionally raised above water level during sedimentation.

Depositional History

Deposition began with the fluvial Precipice Sandstone, which was transported mainly from west to east. The greatest thicknesses are near the northern eroded edge and in the outlier near Bluff. The isopachs show that the formation extended a long way to the north up the centre of the Bowen Basin. The formation thinned to the east against a basement of low relief, and to the south it overlapped the basement to link up with other areas of Triassic-Jurassic sedimentation in southeast Queensland.

The finer-grained and thinner-bedded Evergreen Formation was laid down in a lacustrine environment. The earlier fluvial environment migrated to the northwest, where the partly fluvial, partly lacustrine, Boxvale Sandstone Member constitutes the whole of the formation. The presence of beds of pelletal chamositic mudstone containing acritarchs suggests a possible marine incursion into the Surat Basin during the deposition of the Evergreen Formation. The arenites in the Evergreen Formation, though finer in grain, generally contain more feldspar and lithic material than those in the Precipice Sandstone. The finer grainsize possibly reflects low relief in the provenance areas. Preservation of the labile constituents may have been due to rapid fluvial transport and to little or no reworking. The mineralogical maturity of the Precipice Sandstone may be due mainly to chemical weathering in the fluvial environment rather than to prolonged reworking. The mineralogical and textural maturity of part of the Boxvale Sandstone Member may reflect considerable reworking by waves and currents in shallow water near the western margin of the lake in which the Evergreen Formation was laid down. Regional subsidence may have been responsible for the change from Precipice to Evergreen sedimentation. This could have converted the fluvial environment into a lacustrine environment, lowered the provenance areas, and paved the way for the later marine incursions.

Deposition of the poorly sorted cross-bedded feldspathic sublabile to quartzose sandstone of the lower Hutton Sandstone marks renewed uplift in the provenance areas and a return to deposition in a largely fluvial environment. The comparative mineralogical immaturity of the sediments suggests more rapid transportation and burial than obtained during deposition of the Precipice Sandstone. The presence of salt water in these sediments suggests that they were deposited in brackish water. The upper part of the formation consists of very thick massive beds of fine quartzose sandstone, which indicates considerable reworking in shallow water and possibly a slower rate of supply of sediment. The original distribution of the Hutton Sandstone is unknown. It is very much thicker in the Mimosa and Merivale

Synclines than over the Comet or Nebine Ridges and appears to be thinner to the northwest. It extends across the Birkhead Ridge and is widespread in the Eromanga Basin, unlike the Precipice Sandstone and Evergreen Formation which lens out across the ridge. Deposition of the Hutton Sandstone marks the coalescence of the Surat and Eromanga Basins. Thereafter, sedimentation was continuous from one basin to the other though it differed in some respects. The Hutton Sandstone also marks a major change in provenance areas. Only thin equivalents of the Precipice Sandstone and Evergreen Formations were deposited in local basins in the Eromanga Basin, and high areas in that basin probably supplied sediment to the Surat Basin. This would agree with the cross-bedding dip directions in the Precipice Sandstone, with the westward thinning of both formations, and with the westward migration of the fluvial environment during deposition of the Evergreen Formation. The lensing out of the oolite member and the Westgrove Ironstone Member to the north along the limbs of the Mimosa Syncline indicates a northern limit of the marine(?) conditions favouring this type of sedimentation, and suggests that the northern boundary to the Surat Basin was not far away.

The Hutton Sandstone was probably derived mainly from provenance areas on part of the Clermont Stable Block and the northern part of the Bowen Basin. The labile clasts in the Evergreen Formation consist mainly of granite and metamorphic rocks, while those in the Hutton Sandstone are mainly volcanic rocks (Allan & Houston, 1964). The difference suggests a change in provenance areas.

The Injune Creek Group was deposited during the Middle Jurassic in a variety of environments, but low-energy sedimentation was generally predominant. The basins of deposition were separated by basement ridges, such as the Nebine Ridge. Initially, the Birkhead Formation was laid down in a fluviolacustrine environment grading up into a lacustrine-paludal environment in which coal measures were deposited. West of the Maranoa Anticline, the environment was fluvial and lacustrine, and rarely paludal, and in this area the fluvial Adori Sandstone was laid down on the Birkhead Formation. The cross-bedding azimuths in the Adori Sandstone suggest that it is a tongue of fluvial sand transported south along the synclinal trough west of the Nebine Ridge. The Springbok Sandstone Member at the top of the Birkhead Formation to the east of the Nebine Ridge may be an equivalent tongue of fluvial sand laid down along the trough of the Merivale Syncline. No equivalents of these sands are known east of the Merivale Syncline. The Westbourne Formation was deposited on the Birkhead Formation in the east and on the Adori Sandstone in the west in a widespread lacustrine environment. The cross-bedded and slumped sediments in the Westbourne Formation may be the result of deposition in local deltas on the margins of the lake. Possibly, the sea invaded the area at times.

Upper Jurassic to Lower Cretaceous sedimentation was also divided into two areas by the Nebine Ridge. To the west, the Hooray Sandstone was deposited in a mainly fluvial environment. To the east, the Gubberamunda Sandstone was laid down in a similar environment, while the overlying 'Orallo Formation' (Southlands Formation) was deposited in a fluvial environment changing later to a lacustrine environment; however, the greater proportion of labile material in the 'Orallo Formation' suggests a different provenance from that which supplied the Gubberamunda Sandstone. The Blythesdale Formation consists mainly of a thin quartzose sandstone sequence, which was probably deposited in rivers or lakes, though the abundance of worm borings possibly indicates a paralic environment. An ironstone band at the top of the 'Orallo Formation' may indicate a period of brief subaerial weathering before the Blythesdale Formation was laid down. All three formations are essentially conformable.

The youngest unit of the Great Artesian Basin sequence in the map area is the Roma Formation, which was deposited during a major marine transgression in Aptian time. The presence of coarse and gritty sandstone at the base may indicate some winnowing of the sediments in turbulent water during the initial transgression, but most of the formation was laid down in still water.

STYX COAL MEASURES

The Styx Coal Measures are poorly exposed in a broad area extending south from Saint Lawrence. The best exposures are in cuestas along the western margin of the outcrop area. The Coal Measures were named by Dunstan (in Walkom, 1915), are described in Rands (1892) and Morton (1955), and reviewed in Malone et al. (1969). They consist mainly of interbedded or thick lenses of fine grey sandstone and mudstone, green labile sandstone, coal seams, and a basal pebble conglomerate in places. The Coal Measures unconformably overlie Permian Back Creek Group; they dip regionally to the east at about 5°, but are faulted and folded near their eastern margin against an upfaulted block of the Back Creek Group. The Coal Measures were deposited on the irregular floor of a valley in the trough of the Permian Strathmuir Synclinorium. They were laid down mainly in fresh water, though the presence of microplankton in the sequence may indicate an occasional marine incursion. The plant flora (Walkom, 1919), and spores and microplankton (Cookson & Dettman, 1958) indicate a Lower Cretaceous (Albian?) age.

Isolated outcrops to the south and north are correlated with the Styx Coal Measures because of the similarity in lithology, flora, and stratigraphic position.

TERTIARY

The Tertiary sediments are widely distributed throughout the map area. Most of the sediments were deposited in isolated areas. No fossil remains suitable for correlation have been found, but a crude correlation can be made based on the relationships of the sediments to the basalt sheets and to the main laterite profiles. The basalt sheets have been isotopically dated in some areas, but the age of laterites has not been established.

In the regional survey no attempt was made to subdivide the Tertiary sediments. Several formations have been distinguished in various parts of the basin, and the local stratigraphy has been presented in various Reports (see Fig. 3).

The Tertiary sediments consist of argillaceous quartzose sandstone, conglomerate, siltstone, and claystone, with oil shale and low-rank coal in places. They are generally about 100 m thick in the north, but are locally thicker in deep channels in the pre-Tertiary surface. They are much thicker in the Emerald and Duaringa Sheet areas and in the Callide Valley, where they are up to 210 m thick. The sediments were deposited in fluvial, lacustrine, and paludal environments, and as piedmont fans. Their relatively uniform thickness over most of the area west of the Eungella-Cracow Mobile Belt indicates that they were laid down on a stable continent. They are interbedded in some areas with extensive sheets of basalt and in places were deposited in lakes formed by the damming of rivers by basalt flows.

Up to 1000 m of sediments, apparently all of Tertiary age, were laid down in the elongate Duaringa Basin on the western margin of the Eungella-Cracow Mobile Belt. The basin is bounded on the west by a normal fault. It may have commenced to subside about the end of the Cretaceous as a result of relaxation of compressive stress generated by uplift of the Connors Arch during the Cretaceous orogeny. Seismic surveys indicate that the thick sequence of Tertiary sediments is unconformable on more steeply dipping Permian beds. The shot-hole and water-bore samples, including material down to a depth of 200 m near Duaringa, contain Tertiary spores and fish remains. No information is available on the age of the sediments at depth and the sequence may include Cretaceous sediments.

The Tertiary sediments in the Eungella-Cracow Mobile Belt are restricted to mature valleys such as west of Marlborough and east of Rannes. The lack of Tertiary cover in the northern part of the belt is due to uplift, probably by block faulting during the late Tertiary. Only a few small Tertiary valley fill deposits are preserved on the Connors Arch. One of them, south of Eungella, is capped by Tertiary volcanics, and the total thickness of volcanics and sediments is over 200 m.

The age of the Tertiary sediments is not known precisely. Isotopic ages indicate an Oligocene to Miocene age for the basalts and acid volcanics in the Clermont, Emerald, and Springsure Sheet areas. Here the sediments underlie the basalts and hence are at least as old as Oligocene. Farther north, some of the Tertiary sediments are interbedded with and overlie basalt sheets and could be as young as Miocene. However, the basalt sheets in the north have not been dated and there is no certainty that they are the same age as those in the Emerald Sheet area.

A laterite profile is well developed on the Tertiary sediments capping the mesas around Duaringa and in the Emerald and Springsure Sheet areas. Here, the Tertiary sediments largely pre-date the laterite. The post-basalt sediments in the north, particularly around the headwaters of the Suttor River, have been lateritized to some extent, though the profile is rarely as well developed as in the Duaringa Sheet area. The sediments in the north may have been deposited during a period of lateritization which began in the mid-Tertiary. However, the thickness of the laterite profile may be more closely related to the thickness of easily leached sediments rather than to the duration of the period of lateritization. Thus, the thinner profiles in the north may reflect the thinness of the Tertiary sequence on which they formed, rather than a younger age.

CAINOZOIC

The unconsolidated Cainozoic deposits range from thin soils formed in situ to alluvial deposits up to 120 m thick. They include redistributed Tertiary sediments, lateritic gravels, and sand. Many of the extensive alluvial deposits beside the main watercourses are being incised by the present-day drainage. Many of the black-soil flats represent the remains of decomposed basalt sheets, but elsewhere they appear to overlie Permian sediments.

Sandy soils and lateritic gravels with patches of black soil are most common to the west of the northern part of the basin. Black-soil flats predominate between Emerald and Clermont and north of Clermont.

IGNEOUS ROCKS

The igneous rocks in the map area are mainly confined to the Clermont Stable Block, the Eungella-Cracow Mobile Belt, and the Nebo Synclinorium. They were mapped during the regional survey but were not studied in detail.

The largest intrusions are the Urannah Complex, the Auburn Complex, and the Retreat Granite. Most of the smaller intrusions are unnamed. All the igneous rocks, including Tertiary volcanics are listed in Table 16, which summarizes their distribution, lithology, and relationships. The isotopic ages are based on the results of determinations by A.W. Webb, formerly of the Bureau of Mineral Resources. Most results were obtained by the K/Ar method on mineral concentrates and, in a few samples, on total rocks. Others were obtained by the Rb/Sr method on total rocks, and many of these were checked by the K/Ar method. The validity and significance of the isotopic ages varies considerably. The K/Ar results are subject to an experimental error of about 2 to 3 percent, and the results obtained may not indicate the age of intrusion, but a subsequent period of recrystallization and loss of argon. The Rb/Sr results are dependent on the chemical composition of the samples and their absolute values are suspect because of doubts as to the real value of the Rb/Sr decay constants. The irregular geographical distribution of the samples analysed is another limiting factor on the value of the results. A full discussion of the results are to be presented elsewhere by Webb. All the isotopic ages quoted in this Bulletin are based on Webb's work.

Intrusive History

The oldest known intrusive is the poorly exposed granite in the core of the Telemon Anticline, 58 km west of Springsure, which gave an isotopic age of 450 m.y. A similar age was obtained on mica schist from the Anakie Metamorphics 16 km west of Clermont. Both ages are subject to large experimental errors, but their agreement indicates an intrusive and metamorphic event probably in the Ordovician, which was significantly older than the known ages of other intrusions in the area.

The Ravenswood Granodiorite, cropping out only in the extreme northwest corner of the map area, is an extensive batholith of Silurian to Lower Devonian age (Paine et al., 1969). The batholith and the metamorphics it intrudes form the northern basement to the Drummond Basin.

The gabbro and altered ultrabasic(?) rocks on the axis of the Maranoa Anticline are pre-Jurassic in age and probably very much older. They are unsuitable for age determination, and their contacts with the pre-Jurassic rocks are not exposed.

Retreat Granite

The Retreat Granite (Veevers et al., 1964a) occupies most of the southern end of the Anakie Inlier. It intrudes the Anakie Metamorphics and is unconformably overlain by the Silver Hills Volcanics. Recent mapping in the Clermont area (Olgers, Doutch, & Eftekbaruezhod, 1967) indicates that the Retreat Granite intrudes volcanics correlated with the lower Middle Devonian sequence of Douglas Creek and is unconformably overlain by the Theresa Creek Volcanics. The older volcanics are included with the Theresa Creek Volcanics on the geological map. The Theresa Creek Volcanics are correlated with the Silver Hills Volcanics on lithology and are thought to be late(?) Upper Devonian in age. The Retreat Granite is therefore considered to have been emplaced between the lower Middle Devonian and the late(?) Upper Devonian. The isotopic age of the granite ranges from 345 to 370 m.y. The younger ages were obtained on samples which gave lower ages for biotite than hornblende, which suggests some loss of argon. Biotite and hornblende from six samples gave approximately concordant results of about 365 m.y., and this figure is accepted as the approximate age of intrusion.

Devonian-Carboniferous Intrusives

The Devonian-Carbonifeous intrusives intrude the Lower Middle Devonian Ukalunda Beds at the northern end of the Anakie Inlier and are unconformably overlain by the Upper Devonian(?) to Lower Carboniferous Drummond Basin sequence. Possibly, they are also unconformable beneath the Upper Devonian Mount Wyatt Beds, but this has not been proved. Most of the samples collected have proved unsuitable for isotopic age determination, and only three results have been obtained. Two samples from near the contact with the overlying Bulgonunna Volcanics gave isotopic ages of 290 and 295 m.y. A third sample collected farther from the contact gave an age of 330 m.y. The younger ages agree with the isotopic age of the Bulgonunna Volcanics and probably date a period of recrystallization of the intrusives beneath the thick pile of volcanics. The age of 330 m.y. appears to be too young, as it conflicts with the observed relationship between the intrusions and the Drummond Basin sequence. This is possibly due to loss of argon, or it may be the age of younger components within the Devonian-Carboniferous intrusives.

Carboniferous Intrusives

The Carboniferous intrusives include the youngest plutonic rocks in the Clermont Stable Block. They intrude the unfossiliferous Bulgonunna Volcanics which rest unconformably on the Drummond Basin sequence, and are probably Upper Carboniferous in age. This agrees with the isotopic age of the Bulgonunna Volcanics of 290 to 295 m.y. The Carboniferous intrusives are unconformably overlain by the Lower Permian Lizzie Creek Volcanics. The relationships of the Carboniferous intrusives indicate that they are Upper Carboniferous in age, and this is confirmed by concordant K/Ar and Rb/Sr ages of 285 $\pm$ 5 m.y. Some of the Carboniferous intrusives may be comagmatic with parts of the Bulgonunna Volcanics.

Auburn and Urannah Complexes

The composite Auburn and Urannah Complexes include intrusives of mid-Carboniferous and younger ages. Only part of the Auburn Complex lies within the southeast corner of the map area. The complex is poorly exposed and the relationship of its components to the adjacent Camboon Andesite is uncertain (see above). A number of samples have been dated by both the K/Ar and Rb/Sr methods at about 311 m.y. Other samples from east of the map area have been dated at about 240 m.y. The results suggest that the Auburn Complex consists of a western mid-Carboniferous body and an eastern Upper Permian body.

The Urannah Complex extends to the north of the map area. Its composite nature was indicated by its relationships to the adjacent rock units, and this has been confirmed by the isotopic age determinations. Parts of the complex intrude the Connors Volcanics of Devonian or Carboniferous age. Some elements of the complex intrude the Lizzie Creek Volcanics, some of the boulders in the basal conglomerates of the Lizzie Creek Volcanics were derived from older parts of the Urannah Complex. The intrusive relationships between different components of the complex indicate a number of episodes of intrusion. However, many of the rocks may be genetically related, and may not be very much younger than the rocks they intrude.

A number of samples from the complex were dated by the K/Ar method, and later some of the results were checked by the Rb/Sr method. The combined results indicate three main groups of intrusive rocks, and also suggest that there was extensive recrystallization and loss of argon at times. The oldest group ranges from 311 to 290 m.y.: the upper limit is the age of intrusion of the western part of the Auburn Complex and probably dates a major intrusive event within the Urannah Complex; the lower limit of 290 m.y. is about the average age of the extrusive and intrusive rocks of the Bulgonunna Volcanics and the Carboniferous intrusions near the Urannah Complex. The bulk of the northern part of the complex possibly consists of intrusives emplaced about 290 m.y. ago.

Many of the samples from the northern part of the complex gave K/Ar ages of about 270 m.y. Hornblende from one of these samples gave an age of 283 m.y. and the Rb/Sr results also suggested an older age. These results indicate a period of metamorphism about 270 m.y. ago, which resulted in complete recrystallization of parts of the complex and partial recrystallization and loss of argon elsewhere. The recrystallization may have coincided with the extrusion of the Lizzie Creek Volcanics and Carmila Beds and may be the result of a combination of factors, such as an increase in the geothermal gradient and subsidence of the crust beneath the volcanic pile, and contact metamorphism by the feeder dykes in the volcanics. This part of the Urannah Complex is cut by innumerable dykes, some of which also cut the Lizzie Creek Volcanics. The few dykes which have been isotopically dated are apparently early Upper Permian in age, and are therefore too young to be feeders of the Lizzie Creek Volcanics.

The adamellite in the northern part of the complex (see Thunderbolt Granite, Paine et al., 1969) gave isotopic ages ranging from 260 to 270 m.y. The adamellite was apparently emplaced at depth, and may represent a separate period of intrusion. It is not intruded by the swarms of dykes found in the adjacent parts of the Urannah Complex, which indicates that many of the dykes are older than 270 m.y. Correlation of the dykes with the Lizzie Creek Volcanics implies that the adamellite is younger than the Lizzie Creek Volcanics, and this is compatible with the stratigraphic data and isotopic ages. This implies that it was emplaced in the Connors Arch during the deposition of the thick conformable sequence of sediments in the northern part of the Bowen Basin.

The youngest group of intrusives in the Urannah Complex have isotopic ages of about 125 m.y. - probably early Lower Cretaceous. They are known only in the northern part of the complex. The intrusives of the same isotopic age intruding the Nebo Synclinorium at the northern end of the basin appear to be contemporaneous with the folding of the Bowen Basin sequence. These Lower Cretaceous intrusives were probably emplaced during a period of uplift of the Connors Arch and folding in the northern part of the basin. Most of the known mineralization is apparently associated with these intrusives.

The Urannah Complex was treated as a single unit during the regional mapping, but more recent mapping in the Bowen Sheet area (Paine et al., 1969) has delineated intrusions of different ages within the complex and no doubt this could be extended to other parts of the complex.

The age of the isolated Carboniferous to Mesozoic intrusives intruding the Connors Volcanics and possibly younger rocks to the south of the Urannah Complex indicates that they are related to the Urannah Complex. They include mid-Carboniferous intrusions and dykes of possible Triassic age.

Other Carboniferous to Mesozoic and Permian to Mesozoic intrusives have been mapped east and southeast of Connors Arch. They are mainly adamellite or granodiorite and intrude Carboniferous or Permian rocks.

The only Lower Permian intrusives known outside the Urannah Complex are concordant sills of diorite or gabbro in the Lizzie Creek Volcanics west of Eungella. They are probably contemporaneous with the lavas of the Lizzie Creek Volcanics.

Serpentinite

The serpentinite near Marlborough is intrusive in places into Lower Permian sediments in the Rockhampton Sheet area (Kirkegaard et al., in prep.), though most of the contacts are faulted. The serpentinite is mainly massive, except near faulted contacts, and has contact metamorphosed the sediments to a moderate extent. It was possibly intruded about the start of the Upper Permian. In the southeast, outside the map area, a thin wedge of serpentinite overlies Lower Palaeozoic(?) metamorphics. The structure suggests that it was intruded as a laccolith or large sill. The serpentinite is intruded by a granodiorite with an isotopic age of about 235 m.y. The serpentinite may be a differentiate of the parent basaltic magma of the early Upper Permian spilitic Rookwood Volcanics farther south.

Upper Permian Intrusives

The Upper Permian stocks and plutons are confined to the Gogango Overfolded Zone and the Marlborough Block. Farther east and south in the Port Clinton, Rockhampton, Monto, and Mundubbera Sheet areas, Upper Permian intrusives of batholithic proportions have been recognized.

The intrusions consist mainly of adamellite, granodiorite, and minor diorite with some small stocks of gabbro and granite. Possibly many of the intrusives described as Permian or Carboniferous to Mesozoic belong to the Upper Permian period of intrusion. No Upper Permian intrusives are known in the northern part of the Eungella-Cracow Mobile Belt, north of the Gogango Overfolded Zone, but the Cretaceous intrusives are apparently confined to this area.

Cretaceous Intrusives

The Cretaceous intrusives can be divided into two groups - early Lower Cretaceous and late Lower Cretaceous. The older group were emplaced about 125 m.y. ago; they include part of the Urannah Complex, and small to large stocks and probably laccoliths intruding the Permian sequence in the Nebo Synclinorium. The largest is the Bundarra Granodiorite which is about 16 km across. The Lower Cretaceous intrusives in the Urannah Complex include the Hecate Granite (see Paine et al., 1969) in the Bowen Sheet area, which crops out over an area of several hundred square kilometres. The intrusives in the Nebo Synclinorium mainly occupy the cores of domes and are roughly concordant with the sediments. They have produced little high-grade contact metamorphism but the country rock is extensively indurated. Vertical shearing can be seen along the contact between the granodiorite and metasediments around the Bundarra Granodiorite. Some of the intrusives on the eastern flank of the Nebo Synclinorium, where the sediments have a moderate regional to steep southwesterly dip, are sills, or composite plugs and sills, or dykes.

The Lower Cretaceous intrusives were emplaced during uplift of the Connors Arch and folding in the Nebo Synclinorium. This orogenic pulse affected the northern part of the Bowen Basin only.

The younger Cretaceous group of intrusives were emplaced about 110 m.y. ago. Only a few isotopic age determinations are available. The late Lower Cretaceous intrusives are confined to the northeast coast. The intrusive rocks(Ti) on the islands between Cape Conway and Long Island are similar in lithology and are probably of the same age. They may be roughly contemporaneous with the volcanics(Tv) on Cape Conway and the islands. The volcanics on Cape Conway have been provisionally dated at 112 m.y.

The Mesozoic intrusives around Mackay have not been dated. Some of them intrude Lower Permian rocks; others intrude the Devonian-Carboniferous Campwyn Beds. They could be as old as Lower Permian, but probably belong to one or other of the Lower Cretaceous groups of intrusives. Certainly, the relationships between them indicate more than one period of intrusion.

Cretaceous or Tertiary Intrusives and Extrusives

A trachyte stock intruding the Blackwater Group southeast of Baralaba has given an isotopic age of 70 m.y., approximately at the Cretaceous-Tertiary boundary. A trachysyenite sill 110 km east of Clermont is possibly of the same age as it is similar in lithology.

The post-Permian volcanics crop out only on or near the Connors Arch. They are tentatively regarded as Cretaceous or Tertiary because they appear to be deformed and because they include some plugs similar to those with an isotopic age of 70 m.y. They are possibly related to the late Lower Cretaceous intrusive and extrusive activity on the northeast coast and islands, although they appear to have a different tectonic setting.

Tertiary Intrusives and Extrusives

Basalt

Remnants of basalt flows are widespread in the Bowen Basin. The distribution of the basalt and plugs and dykes indicates three main areas of extrusion, the largest of which covered the southern part of the Clermont Stable Block and the Denison Trough, where 540 m of basalt have been recorded in the Peak Range.

There is another major basalt province in the northern part of the basin, where extensive flows and many plugs are preserved. In the axial region of the Mimosa Syncline, a much smaller quantity of basalt was probably extruded from local vents. Scattered outcrops of basalt in other parts of the basin indicate that basalt flows were very widespread and that many of them have been stripped off by erosion.

The Hoy Basalt consists of a group of basalt plugs which mainly intrude the Retreat Granite. The plugs fill vents from which basalt flowed eastwards into a broad valley trending north through Emerald. The flows around the plugs have been removed by erosion. The plugs are aligned mainly in a north-northeasterly direction with a subordinate easterly trend, and the alignment of the vents was probably controlled by lineaments or fractures in the Palaeozoic basement.

Acid to Intermediate Volcanics

The acid to intermediate volcanics include the Peak Range Volcanics and Minerva Hills Volcanics in the Clermont and Springsure Sheet areas, and unnamed volcanics in the northern part of the basin. Mollan (1965) has made a detailed study of the Peak Range Volcanics. He has shown that the acid to intermediate intrusive and extrusive rocks are differentiates of alkali basalt magma. The Minerva Hills Volcanics are also thought to have been derived from the same parent magma. The Minerva Hills Volcanics are located on the intersection of two prominent basement lineaments: the southeasterly trending partly faulted boundary between the Drummond Basin and the Anakie Inlier, and the northern extension of the Merivale Fault, which forms a hinge-line on the western margin of the Denison Trough. The Peak Range Volcanics are also believed to be related to deep-seated basement fractures.

The volcanics in the northern part of the basin have not been studied closely, but appear to be similar to the Peak Range and Minerva Hills Volcanics. They also are intimately associated with basalt extrusives and intrusives.

The isotopic age of the basalt from the Emerald and Springsure Sheet areas ranges from 33 to 20 m.y.; and the Minerva Hills Volcanics from 28 to 24 m.y. The Tertiary volcanics were probably erupted during a number of separate episodes ranging in age from Oligocene to Miocene.

STRUCTURE

The main tectonic units and structural subdivisions are outlined on Plate 3. The four tectonic units are the Great Artesian Basin in the south, the Clermont Stable Block in the northwest, the central and western parts of the Bowen Basin in the centre, and the Eungella-Cracow Mobile Belt in the east.

The Clermont Stable Block was the site of vigorous orogenic and post-orogenic tectonic movement in the pre-Permian, but has behaved as a stable cratonic block since the inception of the Bowen Basin. The Eungella-Cracow Mobile Belt was the site of repeated orogenic and epi-orogenic tectonism until the end of the Permian and, in the north, again in the Lower Cretaceous. Both are now part of the stable Australian continent.

The Bowen Basin is occupied by the rocks stratigraphically equivalent to and continuous with the Bowen Group (Etheridge, 1872) which were first studied in the Bowen River area. In this sense the basin is a tectonically deformed depositional structure which extends into much of the Eungella-Cracow Mobile Belt. This definition of the basin facilitates a unified treatment of the depositional history and stratigraphy of the entire sequence. Structurally the Bowen Basin, is confined to the area west of the Eungella-Cracow Mobile Belt. However, the term 'basin' suggests a depositional structure rather than a tectonic structure, and we prefer to define it as a deformed depositional structure.

Plate 2 is a block diagram showing the structural units of the basin and of part of the Eungella-Cracow Mobile Belt; the diagram is based on the geological map and sections (Pl. 1), and part of the Eungella-Cracow Mobile Belt.

The structure of the Great Artesian Basin is closely related to the stratigraphy and is described above.

Clermont Stable Block

The Clermont Stable Block is overlapped in the east and south by a thin mantle of gently folded sediments of the Bowen Basin sequence. It forms the shallow basement on the Collinsville Shelf and the Capella Block. It bifurcates to the south around the Denison Trough to form the thinly covered Comet Ridge in the east and the shallow basement of the western part of the Bowen Basin in the west.

The Anakie Inlier is the core of the Clermont Stable Block. The inlier consists of Ordovician or older metasediments, unconformably overlain by and folded with lower Middle Devonian sediments and volcanics, and intruded by Devonian or Carboniferous acid plutonic rocks. Regional metamorphism has produced quartz-mica schist and phyllite in the Anakie

Metamorphics and locally in the Middle Devonian Ukalunda Beds. Elsewhere, the Middle Devonian sediments are unmetamorphosed. Little is known of the complex structure of the inlier.

The Drummond Basin was a major depositional downwarp which was later deformed into an arcuate synclinorium. The rough alignment of the fold axes in the basin parallel to the margin with the Anakie Inlier suggests compressional folding involving westward movement or uplift, or both, of the inlier. The presence of rocks correlated with the Anakie Metamorphics in the core of the Telemon Anticline indicates that the basement to the Drummond Basin was involved in the folding.

In the south, the Drummond Basin trends northwest and has a straight, partly faulted, boundary against the Anakie Inlier. Farther north, the basin trends nearly north and the Drummond Basin sequence laps on to the Anakie Inlier. In the northwest the Drummond Basin trends to the northeast. The change in trend may be due to compression of the basin against the massive Ravenswood Block of Silurian-Devonian igneous rocks and older metamorphics, which crop out in the northwest corner of the map area.

Most of the structures in the Drummond Basin are elongate sinuous faulted domes and basins of great amplitude. In some of the structures the sedimentary sequence is up to 600 m thick. The flanks of the structures rarely dip at more than 40°, and in most of the domes the western flanks are more steeply dipping.

The Drummond Basin sequence probably encircled the northern end of the Anakie Inlier and probably transgressed the inlier near Clermont.

The Mount Rankin Volcanics are a thick sequence of volcanics and sediments overlying the eastern part of the Anakie Inlier. They are only slightly folded and dip to the east at angles up to 45°. The formation is poorly exposed and has not been studied in detail.

The Bulgonunna Wedge in the northeastern part of the Clermont Stable Block consists of a thick pile of acid volcanics (Bulgonunna Volcanics) which lenses out to the west and plunges gently east beneath the northwestern part of the Bowen Basin. The wedge consists of large overlapping relatively homogeneous lenses of volcanics. The structures suggest contemporaneous intrusive and extrusive activity. There are very few folds in the volcanics and most of the dips are probably depositional.

The Joe Joe Formation occupies a wedge at the southern end of the Clermont Stable Block. The wedge is truncated by erosion against the Drummond Basin sequence and dips southwest beneath the western part of the Bowen Basin. The formation has been only gently folded and is gently dipping. The folds are mainly weak reflections of Drummond Basin structures.

The Blair Athol Basin within the Clermont Stable Block is filled with coal measures which have not been folded or disturbed since they were laid down. The sediments are contemporaneous with part of the Bowen Basin sequence.

Central and Western Parts of the Bowen Basin

Western Bowen Basin (=Springsure Shelf)

The Western Bowen Basin is covered by a thin uniform sequence of sediments which were laid down over a long period of time. The sequence probably contains many disconformities, and has undergone little or no tectonic folding. Its tectonic stability was controlled by the underlying Clermont Stable Block. Subsurface data indicate that the southern extension of the Clermont Stable Block was a landmass (the Roma Ridge of Traves, 1966), parts of which extended into the southwestern part of the map area at different times during the Permian and Triassic. The block diagram illustrates the tectonic style in the western part of the Bowen Basin, and the contrast with the adjacent Denison Trough. In effect, the Western Bowen Basin occupies a saddle between the Clermont Stable Block and the Roma and Nebine Ridges.

The western limit of the Western Bowen Basin lies beyond the map area on the southwesterly trending Birkhead Anticline which separates the Bowen and Galilee Basins (Lindner, 1966, Exon, Galloway, Casey & Kirkegaard, in prep.). The lithology of the sediments, particularly the Triassic sediments, changes across the anticline.

Denison Trough (Derrington, 1961)

The Denison Trough was an elongate intracratonic depositional downwarp, flanked to east and west by areas of thinner sedimentation, which shallows abruptly to north and south onto pre-Permian basement. Most of the downwarping took place in the Lower Permian when up to 4500 m of sediments accumulated. Throughout the Upper Permian, Lower Triassic, and Middle Triassic the area subsided slowly and the thickness of the sediment laid down was similar to that deposited in the Western Bowen Basin. The sequence, including the Moolayember Formation, was folded during the late Triassic into the Springsure Anticline and subsidiary anticlines and synclines to the east. The structure of the Springsure Anticline and adjacent folds has been described by Mollan et al. (1969). The axes of the folds generally trend north, parallel to the axis of the Denison Trough. Dips are generally less than 40°, with steeper dips on the west flanks of the anticlines.

The Denison Trough lies within a large basement block - the Comet Ridge and southern extension of the Clermont Stable Block coalesce around the southern end of the trough (see Pl. 2) to form the Roma Ridge.

To the west, the thick sediments of the Denison Trough pass into the thin equivalent sequence in the Western Bowen Basin. The transition takes place across a narrow zone, where the relative movement of the basement was east block down as it subsided to form the Denison Trough. The movement almost certainly involved some faulting and the western boundary of the Denison Trough is probably located on a basement fault zone. The Merivale Fault (Traves, 1966) also lies along the western boundary of the Denison Trough. The movement on the Merivale Fault has affected the Bowen Basin sequence, but not the Great Artesian Basin sequence. The movement is west block down - the reverse of the Lower Permian movement along the same line. The Merivale Fault may reflect renewed movement on the fault zone along the western boundary of the Denison Trough in post-Permian/pre-Jurassic time.

This movement, which probably involved uplift of the basement on the western side of the Denison Trough, was possibly the cause of the folding in the Denison Trough. The main structure in the Denison Trough is the Springsure Anticline which is adjacent and parallel to the western boundary of the trough. The parallel folds to the east of the Springsure Anticline are much smaller in amplitude and length. Farther east, they pass into low-amplitude sinuous folds similar to those on the Comet Ridge. To the west of the Springsure Anticline a low-amplitude broad syncline overlaps the Western Bowen Basin.

Plate 2 illustrates the intracratonic nature and steeply dipping margins of the Denison Trough during deposition of the Reids Dome Beds. The steep plunge at the southern end of the trough has been substantiated by the Westgrove, Kildare, and Glentulloch wells. Later in the Lower Permian, the trough became more extensive and less pronounced, and the Tiverton and Gebbie Subgroups overlapped the trough to the east and northeast across the Comet Ridge.

Comet Ridge

The Comet Ridge (or Comet Platform of Derrington, 1961) was part of a landmass bordering the Denison Trough in early Permian time. Later in the Lower Permian, the block subsided and was covered by a thin mantle of sediments. Deep subsidence of the eastern part of the block in Upper Permian and Triassic times reduced it to a prominent ridge as shown on Plate 2. In the south, the Comet Ridge merges with the Roma Ridge, which is the southeasterly extension of the Clermont Stable Block. To the north, the ridge broadens and merges into the Clermont Stable Block and with the basement of the Capella Block and Collinsville Shelf.

The broad drape structures on the Comet Ridge are best displayed around Comet by the dome of the Blenheim Subgroup surrounded by the Blackwater Group. Most of the folds in the thin sedimentary sequence on the Comet Ridge are of very low amplitude; they generally involve only 100 to 200 m of sediments and die out in the sediments above and below. Dips are generally 5° or less. Minor ripple folds can be seen on the east flank of the Comet Ridge, particularly in the Sagittarius Sandstone Member; they may be partly due to compaction of the thick coal seams in the underlying Rangal Coal Measures.

Seismic surveys over the Comet Ridge indicate the presence of low-amplitude sinuous anastomosing folds. The anticlines are gently plunging with small isolated culminations.

Capella Block

The Capella Block is covered by a thin basal marine sequence overlain, mainly in the north, by a thick partly freshwater sandstone unit. The structural style is consistent throughout the block and consists of broad drape structures over irregularities in the basement. Flank dips rarely exceed 3°. The horizontal sediments on the Capella Block can be distinguished from those on the Collinsville Shelf, where the sediments are thicker and have a gentle regional easterly dip. The boundary between the Capella Block and the Collinsville Shelf or Comet Ridge acted as a hinge-line; the basement to the east and southeast was tilted downwards during subsidence of the Bowen Basin, but to the west, the basement was overlapped during the Upper Permian transgression and subsided vertically to accommodate the freshwater sequence. The rigid basement block protected the sediments on the Capella Block from tectonic folding. The Tertiary Peak Range Volcanics are located near the western margin of the Capella Block which is probably bounded by a major fracture zone in the basement.

Collinsville Shelf (Malone, 1964b)

The Permian to Triassic sediments on the Collinsville Shelf are only gently folded. They dip gently and thicken towards the east (UGC, 1963). Folding increases towards the margin of the shelf where it grades into the Nebo Synclinorium. The transitional zone between the Collinsville Shelf and the Nebo Synclinorium is probably a basement hinge-line where the basement dips more steeply to the east below the synclinorium (see Pl. 2). In places, the boundary is marked by thrust faulting, east block up.

Nebo Synclinorium (Malone, 1964b)

The Nebo Synclinorium contains up to 6000 m of folded and intruded sediments. It was the site of deep subsidence of the basement and severe tectonic folding of the sediments, particularly in the east. Some zones of local uplift associated with the folding may be the result of igneous intrusion. There is no evidence of post-depositional uplift of the basement beneath the synclinorium.

The folds consist mainly of large-amplitude elongate domes, anticlines, and synclines, which tend to die out up section. The Triassic Clematis Sandstone and Moolayember Formation are much less tightly folded than the underlying Rewan Formation and Blackwater Group. The Clematis Sandstone and Rewan Formation are apparently conformable, but in places, the Clematis Sandstone is faulted against more steeply dipping Rewan Formation. During the orogeny the Clematis Sandstone was possibly covered by only a small thickness of sediment, and the competent sandstone tended to shear rather than fold. The Clematis Sandstone is intruded only by dykes associated with a gabbro plug at the northern end of the Redcliffe Tableland. The sandstone is gently domed about the intrusion, and the dykes occupy a set of radial fractures.

On the east limb of the Nebo Synclinorium, in the northern part of the basin, most of the Permian sequence crops out along a strike length of about 130 km. The sequence generally dips southwest into the basin at 30° to 45°, but in places the limb is vertical and locally overturned, with severe shearing and minor thrust faulting. The steep dips, overturning, and shearing are probably related to block uplift of the Connors Arch.

Folded Zone (Malone, 1964b)

The Folded Zone (part of the Dawson Tectonic Zone of Derrington, 1961) is described in Malone et al. (1969). It has been separated from the Nebo Synclinorium because of its distinctive tectonic style, but the boundary between them is poorly exposed. The Folded Zone contains a great thickness of indurated and tightly folded sediments, which have apparently not been intruded by igneous rocks. The folds are generally very tight steep-flanked structures with sharp gently to steeply plunging noses. Reversals of plunge along the axes are common. Tight low-amplitude minor folds are common on the flanks of the larger structures. In general, the folds become broader and the flank dips gentler to the west and north. The folds in the oldest rocks are more open and of larger amplitude than the folds in younger sediments in the same area, and it is probable that the tightness of folding decreases in depth. Seismic surveys across the Folded Zone indicate a flat-lying basement at about 6000 m (Robertson, 1961), and it appears that the structures probably die out at depth near a decollement surface.

Cleavage is virtually absent, and jointing and faulting are relatively uncommon in the Folded Zone. The lack of shear cleavage in the Folded Zone contrasts with the strongly developed axial-plane cleavage in the Gogango Overfolded Zone, even in only moderately folded rocks.

The Folded Zone generally grades into the Comet Ridge and Mimosa Syncline with a gradual reduction in the intensity of folding. Locally, the boundaries are sharply defined by thrust faults or high-angle reverse faults separating the tightly folded sediments to the east from the gently dipping sediments to the west. The sense of movement on these faults is usually east block up.

The presence of a possible decollement below the zone, the reduction in intensity of folding to the west, the presence of local thrust faults on the western margin, and the lack of cleavage suggest gravity tectonics as the most likely mechanism of folding. The Connors Arch has been greatly uplifted since the Permian, and this uplift may have been the source of energy for the gravity tectonics.

The southern part of the Folded Zone, between the Mimosa Syncline and the Gogango Overfolded Zone, is poorly exposed. The folds were probably produced by compressive stress from the northeast, probably during deformation of the Gogango Overfolded Zone. Seismic surveys (Marathon, 1963) indicate numerous easterly dipping thrust faults in this area. The intensity of folding dies out down dip into the broad Mimosa Syncline, and increases to the northeast towards the Gogango Overfolded Zone. Farther north, the relationship between the Folded Zone and the Gogango Overfolded Zone is concealed by the Duaringa Basin.

Mimosa Syncline

The Mimosa Syncline is the main structure in the southern part of the Bowen Basin and the area to the south. The syncline was mainly developed and filled with sediment in the Triassic, when about 5400 m of sedimentary rocks were laid down. In the trough of the syncline the underlying Permian sequence is probably less than 1500 m thick, but it thickens in the east limb. The Mimosa Syncline is mainly an unfolded depositional downwarp. Extensive seismic surveys (Marathon, 1963) in the north have revealed that there was very little minor folding within the syncline. To the south, some relatively large anticlines have been developed, particularly on the east limb of the syncline. Some of these structures grew during the Triassic, and seismic surveys suggest that the Clematis Sandstone rests on a truncated sequence of the Rewan Formation across the crest. The shape, extent, and nature of the Mimosa Syncline is illustrated in Plate 2. The block diagram extends about 25 km south of the map area and presents a simplified picture of the structure near the Wandoan 1 and Burunga 1 wells.

Duaringa Basin

The Duaringa Basin is a narrow trough between the Folded Zone to the west and the Connors Arch and Gogango Overfolded Zone to the east. Seismic surveys across the basin (Robertson, 1961) indicate that it contains about 1000 m of sediments overlying folded Permian rocks. The western margin of the basin is faulted. Most of the sediments in the basin are of Tertiary age, but it is possible that the sediments at the base of the sequence are Cretaceous. The basin lies along a line of moderate gravity minima (Darby, 1966); the gravity data suggest that the deepest part of the basin is at the northern end. There is no evidence of folding in the Duaringa Basin, which is essentially a Tertiary structure superimposed on the Bowen Basin. The basin is bounded by a normal fault on the west, and was possibly developed in response to relaxation of compression after the uplift and folding during the Cretaceous.

Eungella-Cracow Mobile Belt

Connors Arch (Malone, 1964b)

The Connors Arch is part of the 'Eungella strip' of Hill (in Hill & Denmead, eds, 1960, p. 11). In the north, the arch consists mainly of the igneous Urannah Complex and remnants of the Connors Volcanics. Farther south, it consists mainly of Connors Volcanics and isolated intrusives and, northwest of Saint Lawrence it is overlapped by the Lizzie Creek Volcanics and Carmila Beds from the west and east. The arch is a broad simple rigid structure which has been subject to considerable vertical movement since the early Permian. The Lower Permian sediments mainly occupy synclines, which suggests that they were laid down in depressions in the pre-Permian surface. Elsewhere, the Lower Permian sequence is gently dipping and only gently folded.

In the south, the Carmila Beds dip off the arch at 20° to 40° to the east, and the Lizzie Creek Volcanics and Back Creek Group generally dip to the west at less than 20°. In the north, the arch has been uplifted further and the granitic core exposed. The western boundaries are commonly faulted and, in places, the adjacent Permian sequence dips vertically or is overturned. In the north, the eastern margin of the arch is faulted in places, but elsewhere the Cretaceous part of the Urannah Complex intrudes the adjacent Carmila Beds.

Several blocks of volcanics (probably Connors Volcanics) crop out near the southern end of the arch. The blocks have a complex relationship to the overlying Carmila Beds and Back Creek Group, in contrast to the simple relationship between the southern part of the arch and the overlying Permian rocks. These separate blocks of Connors Volcanics apparently formed local high areas during the deposition of the Permian sequence, and appear to have moved independently of the arch during the deposition and deformation of the Permian sequence. The geology of the blocks has been described in detail by Malone et al. (1969) and is only briefly discussed below (Leura area and Strathmuir Synclinorium).

Calen Area

The Calen area, between the Connors Arch and the Campwyn Block, is separated from the Carmila Syncline to the south by a ridge of Devonian-Carboniferous rocks linking the Connors Arch and the Campwyn Block. The structure of the area is uncertain. The central part is occupied by the

Calen Coal Measures which are folded into a broad northerly trending syncline or elongate basin complicated by faulting and minor folding. The Calen Coal Measures generally dip at 20° or less and rest unconformably on the Carmila Beds and Lizzie Creek Volcanics.

The block of Lizzie Creek Volcanics is partly faulted against the Urannah Complex. The Cretaceous intrusives of the Urannah Complex to the north of the fault may be intrusive into the Lizzie Creek Volcanics. The volcanics are thought to be a tongue interfingering with the Carmila Beds.

In the south, the Carmila Beds are apparently folded into a broad complex northerly plunging syncline, interrupted by isolated blocks of the Urannah Complex, which may be unconformable beneath or intrusive into the Carmila Beds. In the north, the Carmila Beds are steeply dipping adjacent to the Urannah Complex which may be partly intrusive into them. The Carmila Beds generally dip away from the contact towards the Urannah Complex.

The eastern boundary of the Calen area is commonly defined by faults separating the Carmila and Campwyn Beds. The faults are mainly east block up. Elsewhere, the Carmila Beds rest unconformably on the Campwyn Beds.

A major east-west lineament crosses the area from Mackay to Eungella. The Pioneer River Valley follows the lineament, but the structure is concealed by thick alluvial deposits. The lineament coincides roughly with the southern margin of the Calen Coal Measures.

Campwyn Block

The Campwyn Block consists of an upfaulted block of Devonian to Carboniferous Campwyn Beds extending along the coast from Repulse Bay to West Hill Island. In the south, the Campwyn Beds are folded into an anticline which trends parallel to the block, but elsewhere the folding of the Campwyn Beds does not appear to be unrelated to the block.

The Campwyn Block is flanked to the east by a Tertiary graben, most of which lies beneath the sea and was mapped by aeromagnetic survey (Aero Service Ltd, 1963) and marine seismic surveys (UGC, 1966; WGC, 1964). The basin extends southwards from Repulse Bay and probably links up with the Cretaceous Styx Basin. About 1260 m of probable Tertiary sediments were intersected in the Prosperine 1 well, a few miles north of the map area.

The islands to the east of the Tertiary basin are composed of probable Cretaceous volcanics and intrusives. The islands are aligned along a northwesterly axis.

Carmila Syncline (Jensen et al., 1966)

The nose and west limb of the Carmila Syncline are exposed east of the Connors Arch. The east limb is partly truncated by the uplifted Campwyn Block and, farther south, is overlapped by the Tertiary offshore basin. The Carmila Syncline is a broad structure occupied by the thick Carmila Beds. Near Saint Lawrence, the folding of the Carmila Beds becomes more complex and the Carmila Syncline passes into the Strathmuir Synclinorium.

Strathmuir Synclinorium (Malone et al., 1969)

The northerly trending Strathmuir Synclinorium is occupied by the Carmila Beds and Back Creek Group. Near Saint Lawrence, the Carmila Beds are folded into many tight minor folds and the Back Creek Group is preserved in a fairly broad, but poorly exposed, easterly to southeasterly trending syncline. The west limb of the synclinorium dips mainly to the east, with some local tight folding. It is interrupted by a block of Connors Volcanics, which is faulted against the easterly dipping Carmila Beds between the block and the Connors Arch. The Apis Creek syncline to the south of the block of Connors Volcanics is partly squeezed between the block and the Connors Arch.

The central part of the synclinorium is moderately tightly folded and faulted; the intensity of deformation increases eastwards towards the overfolded and sheared rocks in the Gogango Overfolded Zone. The east limb of the synclinorium is represented by a single block of Carmila Beds, west of Herbert Creek, in which the beds dip southeast to south into the synclinorium. At the boundary with the Gogango Overfolded Zone, the strike of the beds swings almost north and the dip is generally to the east.

Styx Basin

The Styx Basin is an elongate basin, plunging gently to the north, superimposed on the Strathmuir Synclinorium. The basin is filled with Lower Cretaceous sediments, which dip gently to the east and unconformably overlie the Back Creek Group. The basin is bounded on the east by a high-angle reverse fault, along which the block of tightly folded Back Creek Group to the east has been uplifted, and against which the Cretaceous sediments are folded and faulted.

The Styx Basin is open to the north under the sea and is possibly continuous with the offshore Tertiary basin flanking the Campwyn Block.

Leura Area

The Leura area is a small structural unit at the southern end of the Connors Arch. It consists of folded sediments of the Back Creek Group and a large inlier of Connors Volcanics. The sediments are folded into a series of domes and basins, elongated north-south. The regional dips are generally less than 30°, and although the beds are not overturned, cleavage is well developed. Farther north, near the Connors Arch, the sediments are folded into broad anticlines and synclines plunging south parallel to the plunge of the Connors Arch. A steep easterly dipping cleavage is common in the lutites. A few kilometres to the northwest, similar sediments on the west flank of the Connors Arch are uncleaved, probably because they were protected from deformation by the rigid Connors Arch.

The inlier of Connors Volcanics in the Leura area has greatly influenced the deformation of the sediments. The lowermost 600 m of sediments dip consistently east at low angles, but in the sequence above the structural complexity rapidly increases and the rocks grade into the Gogango Overfolded Zone. The structural complexity appears to be directly proportional to distance above the Connors Volcanics.

Farther west, in the elongate embayment within the inlier of Connors Volcanics, the Back Creek Group sediments are tightly and complexly folded, cleaved and, in places, sheared. The western margin of the embayment is possibly faulted. The intense folding of the Back Creek Group in the embayment is attributed to squeezing between blocks of Connors Volcanics. On the western margin of the Connors Volcanics inlier the Back Creek Group sediments are tightly folded and cleaved, but the intensity of folding decreases rapidly to the west. It appears therefore the blocks of Connors Volcanics acted as rigid mobile blocks which transmitted the compressive stress from east to west, while to some extent protecting the overlying sediments from deformation. Relative movement between the blocks of Connors Volcanics has produced the most severe deformation of the sediments.

Gogango Overfolded Zone (Malone, 1964b)

The Gogango Overfolded Zone is a long arcuate belt composed mainly of Permian sediments and volcanics with some inliers of pre-Permian volcanics. The zone is characterized by overfolding, with easterly dipping axial planes, by faulting and possibly thrust faulting, and by the widespread development of cleavage in the finer sediments. It is difficult to interpret the structure because of the complex stratigraphic relationships and the similarity of the rocks. In general, the pre-Permian inliers and blocks of Lower Permian volcanics have acted as competent masses during the post-Permian folding. They are only moderately folded and are commonly faulted against tightly folded and sheared sediments.

The Boomer Formation, the youngest unit in the zone, is the most intensely folded, particularly where it consists of thinly interbedded siltstone and sandstone. The well developed bedding and rapid alternation of beds with a different degree of competence resulted in flexural slip folding. The style of folding varies with the thickness and competence of the sandstone interbeds. Flexural slip folding, with rectangular troughs and crests, is common where the sandstone beds are up to 30 cm thick and constitute more than half the section. Tight complex folding with many recumbent structures has been developed where the formation consists of thinly interbedded mudstone and fine sandstone. Cleavage is well developed in the Boomer Formation, but there is no evidence of shear folding involving movement along cleavage planes. The Rannes Beds are fairly massive and fine-grained, and have been deformed mainly by movement along shear and cleavage planes. In most areas, the Rannes Beds have been overturned and have a consistent easterly dip. Recumbent folds have been developed in places.

In the eastern part of the zone, a complex syncline, west of the Craigilee area, is outlined by broadly folded Rookwood Volcanics, and the trough is filled with tightly folded beds of the Boomer Formation. Farther west, there are complex structures involving inliers of Silurian-Devonian volcanics with the Rookwood Volcanics and Boomer Formation. The Boomer Formation apparently overlapped the Rookwood Volcanics and rests directly on the Silurian-Devonian volcanics in places. During deformation, the Boomer Formation was folded and the volcanics were moved by block faulting, so that in one place the Boomer Formation dips steeply beneath the Rookwood Volcanics and in another place, a few kilometres to the south, it rests conformably on the Rookwood Volcanics.

Craigilee Area

The Craigilee Anticline is composed of Carboniferous sediments resting unconformably on Silurian-Devonian rocks in the core of the structure. The Devonian-Carboniferous rocks extend to the west. The Silurian-Devonian rocks consist mainly of massive volcanics, with some steeply dipping sediments which are tightly folded in places. The strike of the older rocks is almost at right angles to the strike of the younger sediments. On the east flank of the anticline the Carboniferous rocks dip at about 45°, but in the west they are locally overturned, and in places the Rookwood Volcanics overlap the Carboniferous sediments and rest directly on the Silurian-Devonian rocks. The Devonian-Carboniferous sediments to the northwest of the Craigilee Anticline dip east and northeast at 40° to 70°. The sediments are overlain by the Rookwood Volcanics, and in the west by the Youlambie Conglomerate which is possibly faulted against the Rannes Beds.

Marlborough Block

The Marlborough Block consists of possible Lower Palaeozoic metamorphics and late Lower Permian serpentinite intruded by Upper(?) Permian gabbro and granodiorite. The serpentinite sheet is generally unsheared. It forms a long narrow strip along the northwest margin of the Marlborough Block, where it is faulted against Lower Permian rocks and is commonly sheared. The faulted margin dips steeply southeast. In most areas, the metamorphics have a well developed steeply dipping schistosity which trends east to northeast. One of the faults in the Marlborough Block has displaced the laterite profile on the serpentinite and is probably of Tertiary age. The contact between the Marlborough Block and the Craigilee area is not exposed, but in the Port Clinton Sheet area to the east, the serpentinite intrudes sediments which are probably equivalent to the Silurian-Devonian rocks. The serpentinite was intruded in the late Lower Permian, possibly at the same time as the Rookwood Volcanics were extruded farther south. The Marlborough Block was possibly upfaulted against the Carmila Beds in the Upper Permian, before or during the Upper Permian intrusive episode.

Long Island Area

The Long Island area consists of moderately folded Devonian to Permian sediments of the Yarrol Basin sequence faulted to the south against Lower Palaeozoic(?) metamorphics which are intruded by a poorly exposed Carboniferous or younger granodiorite. The Yarrol Basin sediments strike north to northeast and dip mainly to the east. The sequence has probably been folded into a large north-trending syncline, only the western limb of which is exposed.

Auburn Arch (Malone, 1964b)

The Auburn Arch consists mainly of the massive Auburn Complex overlain by pre-Permian volcanics. In the north, it may include some Lower Permian volcanics which extend into the Gogango Overfolded Zone. The arch acted as a moderately stable rigid block during the Permian and younger deformations. It is flanked to the west by the moderately steeply dipping east limb of the Mimosa Syncline. To the east, tightly folded and faulted Permian sediments are compressed against the arch. The most recent mapping (Dear et al., in press) indicates that the arch is cut by a number of northeasterly faults.

Prospect Creek Area

The Prospect Creek area is occupied by tightly folded and faulted Permian sediments and volcanics. The fold axes and faults generally trend nearly north, parallel to the boundary of the Auburn Arch, which suggests that the sediments have been compressed against the arch by stress from the east.

Biloela Basin

The Biloela Basin is covered by an extensive but thin sequence of Tertiary sediments and Cainozoic alluvium, which conceal the underlying structures.

GEOLOGICAL HISTORY

Clermont Stable Block (pre-Permian rock units)

The Anakie Metamorphics include the oldest known rocks in the Clermont Stable Block. Samples of mica schist, and of one of the granites which probably intrudes the metamorphics, have given isotopic ages of about 450 m.y. The metamorphics are therefore Ordovician or older. The formation was folded, intruded, and thermally and regionally metamorphosed prior to the deposition of the marine Lower to Middle Devonian sediments.

The Middle Devonian sediments were laid down in a warm sea, which favoured the growth of reef limestones, and the marine clastic and carbonate sedimentation was accompanied by considerable contemporaneous vulcanism. The thick and extensive Ukalunda Beds were deposited at the northern end of the Anakie Inlier. Only small areas of Middle Devonian rocks have been recognized farther south, the most southerly of which consists of about 600 m of Dunstable Volcanics. The Middle Devonian sedimentation was probably extensive, and some unrecognized Middle Devonian sediments may be present in the Anakie Metamorphics. Vulcanism was most active in the south, where volcanics form the bulk of the Dunstable Volcanics and much of the Middle Devonian rocks west of Emerald and near Douglas Creek. The fossils in the Ukalunda Beds, and in the Douglas Creek Limestone and equivalents, indicate a lower Middle Devonian age; those in the Dunstable Volcanics are probably also lower Middle Devonian. However, sedimentation probably began in the Lower Devonian and continued into the upper Middle Devonian.

The Middle Devonian sediments were deposited unconformably on the Anakie Metamorphics, and both were folded and intruded by the Retreat Granite and Devonian-Carboniferous intrusives, probably during the Upper Devonian.

The only Upper Devonian sediments known in the Clermont Stable Block are the fossiliferous marine Mount Wyatt Beds, which were laid down near the northern end of the Anakie Inlier in the Famennian. They are the only record of a brief incursion of the sea into the area after the Middle Devonian, and all the succeeding sediments were apparently deposited in fresh water.

In the late Upper Devonian or early Carboniferous, acid to intermediate volcanics were extruded in a province which overlapped the Anakie Inlier to west and east, but probably did not extend much farther north than Mount Coolon. The vulcanism produced the Silver Hills Volcanics in the west, the Theresa Creek Volcanics on the Anakie Inlier, and the volcanics in the lower part of the Mount Rankin Beds to the east. The vulcanism was probably largely terrestrial and took place before uplift of the Anakie Inlier and subsidence of the Drummond Basin.

The Telemon Formation at the base of the Drummond Basin sequence contains considerable reworked volcanic detritus, which was probably derived from the Silver Hills Volcanics. The quartz-rich Mount Hall Conglomerate and Raymond Sandstone succeeded the Telemon Formation with local slight unconformity. They were possibly laid down during a period of slower subsidence and greater reworking of the sediments. The lenses of Mount Hall Conglomerate and similar conglomerates farther north possibly indicate local vigorous uplift of the provenance areas. The Ducabrook Formation, the youngest unit in the Drummond Basin, is similar to the Telemon Formation. At this time, the depositional area possibly overlapped the Anakie Inlier eastwards into the area where the sequence at the top of the Mount Rankin Beds was deposited. Vulcanism on a relatively small scale continued while the Drummond Basin sequence was being deposited.

No equivalent of the Silver Hills Volcanics is present in the northern part of the Drummond Basin, where sedimentation probably commenced earlier - possibly with the marine equivalents of the Mount Wyatt Beds, which are probably older than the Telemon Formation. The remainder of the sequence is similar to the Telemon and Ducabrook Formations, but includes, in places, thick lenses of conglomerate.

The Drummond Basin sequence was strongly folded, probably in the late Lower Carboniferous. The fold axes are generally parallel with the margin of the Anakie Inlier, which influenced and was involved in the folding. Rocks correlated with those in the Anakie Inlier are exposed in the cores of anticlines in the southern part of the Drummond Basin, west of Springsure. The shear cleavage in the mudstone in the northwestern part of the Anakie Inlier is apparently parallel to the axial planes of folds in the Drummond Basin to the west; it was possibly developed in response to the stress which produced the folding in the Drummond Basin. The boundary between the Drummond Basin and the Anakie Inlier is faulted in places. Presumably, the inlier was displaced laterally to the west during the folding, but since then the inlier and the Drummond Basin have retained their present positions. The swing to a northeasterly trend at the northern end of the Drummond Basin and the Anakie Inlier is possibly due to the resistance offered by the Ravenswood Block to westward displacement. The shear stress concentrated near the change of trend probably explains the abundant phyllitic cleavage and schistosity in the Ukalunda Beds in this area.

No igneous activity is known during the folding of the Drummond Basin.

The Mount Rankin Beds are not well exposed, but are apparently not tightly folded. They may have been protected from folding by the Anakie Inlier on which they lie.

Renewed vulcanism in the Upper Carboniferous produced the thick acid Bulgonunna Volcanics which rest unconformably on the Mount Rankin Beds and the folded Drummond Basin sequence. The Bulgonunna Volcanics consist of a pile of heterogeneous volcanic lenses, each of which was probably erupted from a single volcanic focus or group of foci. Some of the lenses probably consist of contemporaneous intrusive and extrusive rocks. The formation is gently folded in places and is on the whole flat-lying or dips to the east. In the late Upper Carboniferous the volcanics were intruded by acid stocks and small batholiths, some of which may be comagmatic with the Bulgonunna Volcanics. A solitary stock, with an isotopic age similar to the late Upper Carboniferous intrusives, intruded the Drummond Basin sequence west of Emerald.

In the south, the late Upper Carboniferous sediments contain glacial detritus. The presence of abundant striated and facetted cobbles and boulders in poorly stratified conglomerate and thinly laminated (varve?) shale in the Joe Joe Formation indicate a glacigene source. The sediments are possibly fluvioglacial deposits laid down beyond the glaciated uplands. The Joe Joe Formation rests unconformably on the Drummond Basin sequence and dips southwest below the Western Bowen Basin; the beds are only slightly folded and the area has been stable since the end of the Lower Carboniferous.

Eungella- Cracow Mobile Belt (pre-Permian rock units)

The Eungella-Cracow Mobile Belt has a complex geological history. Major tectonic activity had ceased in the Clermont Stable Block by the end of the Carboniferous, but in the Eungella-Cracow Mobile Belt it continued spasmodically until the Cretaceous. The rock units are discussed below in probable order of descending age, but little information is available on the age and relationships of many of the units.

Possibly, the oldest rocks in the east are the metamorphics (Pzl) of the Marlborough Block. No fossils have been found, and no isotopic ages are available. They are assumed to be the oldest rocks because they are the most strongly metamorphosed. The metamorphics were intruded by serpentinite about the end of the Lower Permian, when they were possibly uplifted by block faulting into approximately their present position; they were intruded by a granodiorite pluton and smaller stocks in the Upper Permian.

The unnamed Palaeozoic metamorphic rocks (Pz) cropping out 40 km southeast of Theodore are of unknown age. As they are presumably intruded by the Auburn Complex they are probably Lower Carboniferous or older.

The Silurian-Devonian rocks in the core of the Craigilee Anticline are the oldest fossiliferous rocks. They contain an Upper Silurian fauna in one place, and a probable Lower Devonian fauna in others. The sequence contains extensive intermediate to basic volcanics and marine carbonate and minor clastic rocks laid down about the end of the Silurian. The palaeontological data indicate that the sequence is significantly older than the Middle Devonian rocks of the Clermont Stable Block. The volcanics are mainly massive, but the bedded limestone and clastic sediments show that the sequence has been tightly folded. Folding and uplift took place in the Devonian as the overlying Yarrol Basin sequence strikes at right angles to structures in the Silurian-Devonian rocks. The Silurian-Devonian rocks partly controlled the distribution of the Yarrol Basin sequence in the Craigilee area. A conglomerate at the base of the Yarrol Basin sequence contains clasts of fossiliferous limestone from the Silurian-Devonian sediments, and the onlapping of the Carboniferous and Lower Permian units indicates that the Silurian-Devonian rocks were exposed during Yarrol Basin and Bowen Basin sedimentation.

The inliers to the west of the Craigilee area are correlated with the Silurian-Devonian rocks on lithology only. Their relationship to the Permian sediments indicates that they were exposed at times.

The Yarrol Basin sequence has been recognized in the Craigilee and Long Island areas. The Campwyn Beds were probably laid down in a northerly extension of the Yarrol Basin. Deposition of the Yarrol Basin sequence probably began in the Upper Devonian, and consisted mainly of volcanics. Volcanics with an Upper Devonian fauna crop out in the northwest part of the Craigilee area. In the Craigilee Anticline the lithology and fauna are different. The base of the sequence consists of Lower Carboniferous sediments resting unconformably on the Silurian-Devonian rocks. The Silurian-Devonian rocks apparently formed a ridge, which extended into the Yarrol Basin and was progressively overlapped from northeast to south-west. Probable Upper Devonian volcanics and sediments were deposited east of the ridge, but were overlapped by the Lower Carboniferous sediments.

The Yarrol Basin sequence in the Long Island area includes Upper Devonian, Lower and Upper Carboniferous, and Lower Permian volcanics and sediments. The sequence was probably laid down well within the basin, whereas the beds in the Craigilee area were deposited near the shore. The connexion between the Yarrol Basin sequences in the Craigilee and Long Island areas is not exposed; it may be covered by Bowen Basin sediments or was eroded when the Marlborough Block was uplifted.

The history of the Yarrol Basin began with the deposition of volcanics and interbedded sediments in the Upper Devonian. These were succeeded in the Lower Carboniferous by lutite, conglomerate, and oolitic limestone, followed in turn in the Upper Carboniferous by lutite and sandstone, with a little conglomerate and limestone. In the Lower Permian the Youlambie Conglomerate and the conglomerate sequence on Quail Island were laid down. The separate distribution of these units and gaps in the faunal succession suggest the presence of disconformities, some of which are possibly quite large. The disconformities are possibly related to epeirogenic movements, and the absence of angular unconformities indicates that there was no vigorous folding in Upper Devonian/Upper Carboniferous times. The predominance of coarse clastics and the irregular distribution of the Lower Permian sediments in the Yarrol Basin, plus the fact that they are locally unconformable on the Upper Carboniferous, suggest that they were associated with renewed tectonism, probably consisting mainly of vertical block movements. The Yarrol Basin sequence was folded into large structures with local steep flanks, probably during the late Upper Permian orogeny.

The Campwyn Beds consist mainly of pyroclastics and extrusive flows, with minor sediments. The faunas indicate an Upper Devonian and Lower Carboniferous age. Some of the volcanics may be terrestrial, and the Campwyn Beds were possibly deposited along the northwestern margin of the Yarrol Basin. They are folded into fairly large structures and are extensively intruded by small igneous bodies and dykes. They were uplifted and faulted against the Carmila Beds after the early Lower Permian.

The Yarrol Basin sequence is partly contemporaneous with the Mount Rankin Beds and the Drummond Basin sequence, but they were all probably laid down in completely separate areas.

The Connors Volcanics and the older part of the Camboon Andesite, and possibly the older part of the Rannes Beds, are Carboniferous or older. They occupy a structurally high position along the western edge of the Eungella-Cracow Mobile Belt and are unconformably overlain by Permian strata. The Connors Volcanics and the older part of the Camboon Andesite are intruded by igneous rocks with isotopic ages of up to 311 m.y.

The Connors Volcanics consist of massive volcanics, which are extensively silicified, jointed, and intruded. The Connors Arch, which is composed of volcanics and intrusive rocks, was partly exposed at times during the Permian, and had a marked influence on the structural deformation of the Permian rocks. The northern part of the arch was intruded by igneous rocks in Upper Carboniferous and early Permian times, and again in the early Cretaceous. The early Permian intrusions apparently post-date the extrusion of the Lizzie Creek Volcanics.

The Auburn Arch is composed of massive volcanics of the older part of the Camboon Andesite and the intrusive Auburn Complex. Both the Connors Volcanics and the older part of the Camboon Andesite probably include terrestrial volcanics. They may be correlates of the volcanics at the base of the Yarrol Basin sequence, or possibly of the Silurian-Devonian volcanics, or they may represent one or more independent periods of vulcanism which were not related to the activity in the Eungella-Cracow Mobile Belt.

The Rannes Beds between the Connors and Auburn Arches consist mainly of fine clastics with some lenses of limestone and volcanics. Unlike the massive rocks of the Connors and Auburn Arches, they have been cleaved, sheared, faulted, folded, and overfolded. Much of the deformation was the result of Upper Permian or younger tectonic activity, and consequently the Rannes Beds are difficult to distinguish from folded and cleaved Permian rocks of similar lithology. The older part of the Rannes Beds is associated with Connors Volcanics and both are unconformably overlain by the Boomer Formation. The magnitude of the unconformity suggests that this part of the Rannes Beds may be pre-Permian. Most of the unit, however, is probably Lower Permian and was deposited in a marine environment.

The Torsdale Beds at the northern end of the Auburn Arch are considered to be Upper Carboniferous in age (Dear et al., in press.), but these probably extend into the Lower Permian. They include conglomerate of possible fluvioglacial origin, and are roughly the same age as the Joe Joe Formation.

Permian-Triassic

Sedimentation in the Bowen Basin began in three areas in the early Lower Permian with the deposition of the Reids Dome Beds, Lizzie Creek Volcanics, and Carmila Beds. A great thickness of terrestrial sediments (the Reids Dome Beds) accumulated in the Denison Trough, and a thin sheet was laid down across the Western Bowen Basin. The sequence includes mudstone and interbedded coal seams laid down during a period of slow subsidence, and thick lenses of conglomerate deposited during periods of more rapid subsidence associated with uplift of the source areas. Minor contemporaneous vulcanism probably occurred near the eastern margin of the Denison Trough. At the same time, there was a period of major vulcanism to the north and south. In the north the Lizzie Creek Volcanics and Carmila Beds were laid down to the west and east of the Connors Arch, and in the south the upper part of the Camboon Andesite was formed on the

Auburn Arch. The two areas of vulcanism were probably separate. The sediments of the younger part of the Rannes Beds were deposited between the Connors and Auburn Arches, and in the north they were possibly continuous with the Carmila Beds. The Youlambie Conglomerate and its probable equivalent on Quail Island were laid down in the early Lower Permian. Most of the Youlambie Conglomerate was deposited in the Yarrol Basin, but it extended westward into the Bowen Basin where it was possibly continuous with part of the Rannes Beds.

In the north, the period of terrestrial vulcanism was followed by freshwater sedimentation and vulcanism, and finally by marine sedimentation. The upper part of the Camboon Andesite contains lenses of fossiliferous marine limestone northeast of the Auburn Arch. About this time, marine sediments were being deposited in the Yarrol Basin. The sea was apparently to the east of the Connors Arch/Auburn Arch in the early Permian, but transgressed westward into the Bowen Basin about the end of the volcanic cycle. Marine fossils are present towards the top of both the Lizzie Creek Volcanics and the Carmila Beds.

Deposition of the marine Back Creek Group followed during the remainder of the Lower Permian and early Upper Permian. The thick Tiverton Subgroup was laid down in the Denison Trough and in a northern trough extending approximately across the site of the Connors Arch and Nebo Synclinorium. Both sequences consist predominantly of marine mudstone; lenses of littoral and fluviatile sandstone interfinger with the mudstone on the northwest flank of the Denison Trough, and in the north the base of the sequence consists of sandstone, siltstone, and coquinite. Vulcanism continued at the southern end of Connors Arch, where the Tiverton Subgroup pyroclastics include reworked volcanic material. A thinner and possibly discontinuous sequence was laid down on the Comet Ridge between the two troughs. Only the basal part of the subgroup is represented in the southeastern part of the basin, where thin neritic limestone and calcareous tuffaceous rocks were deposited over the Auburn Arch and discontinuously over the area between the Connors and Auburn Arches. The area was apparently uplifted during the late Lower Permian and the Boomer Formation rests with moderate angular unconformity on the Lower Permian sediments.

The Gebbie Subgroup was deposited in the late Lower Permian. The northern trough became more shallow and expanded westwards beyond the Nebo Synclinorium. Near the Connors Arch, interbedded quartz sandstone and mudstone were laid down on the underlying mudstone, and in the northwest the Collinsville Coal Measures were deposited in a deltaic environment. East of Connors Arch, the Calen Coal Measures were possibly deposited at about this time. In the late Lower Permian a thick sequence of fluviatile and marine littoral sandstone with interbeds of mudstone were laid down in the Denison Trough. At the same time a thinner sandstone sequence was deposited over the Comet Ridge and a thin sheet of fluviatile sandstone (the Colinlea Sandstone) was laid down in the Western Bowen Basin.

The Blair Athol Coal Measures were laid down in an isolated basin within the Clermont Stable Block during deposition of the Gebbie Subgroup. The Blair Athol basin is on line with the Denison Trough and possibly represents an extension of this trough.

The Blenheim Subgroup was deposited in the early Upper Permian. It consists of a thin blanket of marine sediments in the Western Bowen Basin and in the Denison Trough. At the same time, the northern trough deepened and expanded, and a thick pile of sediments were laid down near the western margin of Connors Arch; farther west, a thinner sequence of sandy sediments with local freshwater and marine coal measures was deposited on the Collinsville Shelf, the Capella Block, and Comet Ridge. The sea transgressed farther west in the Upper Permian than in the Lower Permian, and on the Clermont Stable Block the Blenheim Subgroup rests unconformably on the pre-Permian rocks.

The most marked early Upper Permian subsidence took place on the site of the Auburn Arch and Gogango Overfolded Zone, and beyond the eastern margin of the map area. In the Gogango Overfolded Zone, the submarine spilitic Rookwood Volcanics were extruded unconformably on the Lower Permian Youlambie Conglomerate and older rocks. They initiated the cycle of sedimentation in this deep but restricted Upper Permian downwarp. The serpentinite of the Marlborough area was emplaced about the end of the Lower Permian. It may be comagmatic with the Rookwood Volcanics, and both were possibly related to the Upper Permian downwarping. The Boomer Formation was deposited in the Gogango Overfolded Zone downwarp. It overlapped and locally interfingered with the Rookwood Volcanics, and to the east it interfingered with units containing immature conglomerate derived mainly from the east. At the same time, a predominatly lutite sequence was deposited near the Auburn Arch. Considerable local extrusive volcanic activity was associated with Blenheim Subgroup sedimentation near the Auburn Arch, and the presence of tuffaceous clays in the Black Alley Shale of the Denison Trough and western part of the basin indicates that the effects of vulcanism extended far to the west. No pyroclastic rocks or flows have been recognized in the Blenheim Subgroup in the north. Some of the youngest sediments of the subgroup are non-marine, and almost all the sediments laid down in the Bowen Basin from this time onwards are non-marine.

In late Upper Permian time, the Blackwater Group was deposited in a changing system of river channels, braided streams, flood-plains, lakes, and swamps, in the central and western parts of the basin. In the east, uplift along the line of the Connors and Auburn Arches converted the marine basin to a freshwater depositional area. In the late Upper Permian numerous acid intrusions were emplaced in the southern part of the Eungella-Cracow Mobile Belt, particularly in the southeast. The intrusive activity was probably associated with uplift of the mobile belt, although the isotopic ages indicate that most of the intrusions were emplaced during or at the end of Blackwater Group time. This late Upper Permian orogeny probably produced most of the deformation within the Gogango Overfolded Zone.

The Blackwater Group consists of coarse to fine clastics, followed by a sequence of fine clastics with widespread interbeds of volcanic ash, and finally of coal measures composed mainly of carbonaceous mudstone, minor sandstone, and many thick seams of coal. The group is about 2000 m thick in the Nebo Synclinorium, where the northern trough continued to subside. It ranges from 360 to 600 m thick on the Comet Ridge and under the Mimosa Syncline, but is very thin and probably not fully represented over the Denison Trough and in the Western Bowen Basin. In the Nebo Synclinorium there were probably several episodes of vulcanism which contributed detritus to the Blackwater Group, but elsewhere only one, about the middle of the unit, is recognized.

The Lower Triassic Rewan Formation, which succeeded the Blackwater Group, was deposited over much the same area, but the locus of sedimentation shifted from the Nebo Synclinorium to the Mimosa Syncline. The Rewan Formation consists mainly of red and green mudstone and siltstone, with green sandstone. Beds of conglomerate are found near the base in places. Little carbonaceous material and few plants are preserved in the Rewan Formation though they are abundant in the Blackwater Group. The paucity of carbonaceous material and the red colour of the sediments suggest that the Rewan Formation was deposited in a non-reducing environment, possibly as a result of climatic changes at the end of the Permian. The red sediments were apparently derived from laterite profiles developed during post-Permian lateritization of the provenance areas; that is, the red colour is a primary feature.

The fluviatile Clematis Sandstone was laid down over the Rewan Formation. Its maturity and uniform thickness indicate deposition under conditions of slow uniform subsidence of the central and western parts of the basin. Rapid subsidence of the Mimosa Syncline began again in the Middle or Upper Triassic, and the immature Moolayember Formation succeeded the Clematis Sandstone. The thickest part of the Moolayember Formation was laid down in the Mimosa Syncline, and the sequence is relatively thin in the western and north-central parts of the basin. About 5400 m of sediments were deposited in the Mimosa Syncline during the Triassic. Acid igneous rocks intruded the eastern zone during the Triassic, and the downwarping of the Mimosa Syncline was possibly counterbalanced by uplift and intrusion to the east.

During the Upper Triassic deposition ceased in the Bowen Basin, and the sediments were uplifted and eroded. During these movements, the east flank of the Mimosa Syncline was steepened, and the major structures in the Denison Trough, which probably commenced to form during downwarping of the Mimosa Syncline, were more tightly folded and then truncated by erosion.

Jurassic-Cretaceous

Deposition in the Great Artesian Basin began early in the Jurassic with the fluviatile Precipice Sandstone, which blanketed the area as the basin began to subside. A lacustrine, and at times possibly marine, environment developed in the east, where the fine sediments and some oolitic ironstone of the Evergreen Formation were deposited. Farther west, the Evergreen Formation consists mainly of the cross-bedded Boxvale Sandstone Member which was laid down in a persistent fluviatile environment. The fluviatile environment advanced over the whole area again when the Hutton Sandstone was deposited at the end of the Lower Jurassic. In the Middle Jurassic, the area was occupied by lakes and swamps in which the fine sediments and minor chemical precipitates and coal of the Injune Creek Beds were deposited. In the Upper Jurassic and early Cretaceous, alternating fluviatile sand and partly lacustrine sands and muds were laid down. A major marine transgression covered the area in the Lower Cretaceous, when the mudstone, glauconitic sandstone, and limestone of the Roma Formation were deposited. These sediments are the youngest in the Great Artesian Basin within the map area.

Cretaceous sedimentation outside the Great Artesian Basin was confined to small areas. Freshwater sandstone, conglomerate, siltstone, and coal, of Lower Cretaceous age, are preserved in the Styx Basin and in small areas to the south and northeast, but they were probably deposited over a much wider area. The minor marine incursion in the Styx Basin sequence may be related to the major marine transgression of the Roma Formation in the Great Artesian Basin.

The early Lower Cretaceous was a time of considerable tectonic activity in the north. Acid to basic igneous rocks intruded the northern end of the Connors Arch and the Permian-Triassic sequence of the Nebo Synclinorium, probably during folding of the Permian-Triassic rocks. The Eungella-Cracow Mobile Belt was possibly again uplifted at this time and the sediments of the Gogango Overfolded Zone were further deformed. The folding of the Folded Zone is tentatively correlated with this uplift.

Renewed intrusive and extrusive activity took place about the end of the Lower Cretaceous along the northeast coast and offshore to the northeast.

Trachyte stocks, such as those south of Baralaba, were intruded about the end of the Cretaceous.

Cainozoic

Most of the Tertiary volcanics and sediments are poorly known, and as mapped they may include some pre-Tertiary rocks. The isotopic age determinations indicate that the main period of extrusion of the basalts and associated acid differentiates took place 30 to 20 million years ago, that is during the late Oligocene to early Miocene.

The Tertiary sediments were deposited in rivers, flood-plains, and temporary lakes on a land surface similar to the present topography. Some of the lakes were formed as a result of damming of the rivers by basalt flows. The sediments rarely exceed 200 m in thickness, but much greater thicknesses accumulated in small faulted basins, such as the Duaringa Basin, where they are about 1000 m thick.

The area was subjected to a prolonged period of lateritization during the Tertiary, and thick laterite profiles were developed on the permeable poorly consolidated Tertiary sediments. Locally, laterite profiles were also developed on the basalt sheets and pre-Tertiary rocks, and on the serpentinite and igneous rocks of the Marlborough area. Some of the laterites on the older rocks may be of Cretaceous age. The laterite profiles on the serpentinite have been displaced by late Tertiary faulting and the laterite is preserved on the downfaulted block only. The laterite profile on the Tertiary sediments has been preserved on tablelands and mesas in many areas, and once the laterite profile has been completely removed, the Tertiary sediments are readily eroded.

The Cainozoic sediments were deposited in braided streams, flood-plains, and river channels closely related to the present drainage system, which is actively eroding the older Cainozoic rocks. The sediments are generally less than 60 m thick, though thicknesses of up to 120 m are known in some river valleys.

Uplift of the Connors Arch during the late Tertiary is indicated by the difference in lithology between Tertiary sediments and younger Cainozoic sediments in the same position relative to the Connors Arch: the older rocks are mainly fine sandstone and siltstone; the younger sequence is a locally derived boulder conglomerate. Other minor uplifts are indicated by incised younger streams which truncate the probable Pleistocene or younger river-channel deposits.

ECONOMIC GEOLOGY

Most of the metalliferous deposits are found in two belts of igneous and metamorphic rocks to the east and west of the basin proper, but the Mount Flora copper deposits are associated with the Bundarra Granite in the Back Creek Group. The sapphires of Anakie are derived from Tertiary volcanics in the western belt of igneous and metamorphic rocks. The Bowen Basin contains important deposits of coal and groundwater. Despite extensive exploration and drilling no oil or gas is being produced, although commercial oil and gas fields have been found to the south.

The mineral occurrences and production have been given by McLeod (1965), and information on minerals, mining, and groundwater is being prepared for the Department of National Development, Fitzroy Region, Queensland, Resources Series.

Groundwater

A survey of the underground water resources of most of the area has been made by the Department of National Development in conjunction with the Geological Survey of Queensland and the Irrigation and Water Supply Commission of Queensland (Department of National Development, in prep.). During the regional survey data on water bores were collected, and the results have been tabulated in the reports on the Sheet areas. In the south some of the important aquifers lie in the Great Artesian Basin and form part of the intake area for the basin. They include the Precipice Sandstone and the Boxvale Sandstone Member of the Evergreen Formation, both of Jurassic age.

Much remains to be done on engineering aspects and potential.

Coal

The Bowen Basin is one of the most important black coal-producing areas in Australia, second only to the Sydney Basin.

Coal has been recorded from many stratigraphical levels in the Permian, Jurassic, and Cretaceous rocks.

Permian

Coal has been recorded in the Reids Dome Beds (subsurface only), Aldebaran and Colinlea Sandstones, Blair Athol Coal Measures, Collinsville Coal Measures (Gebbie Subgroup), Calen Coal Measures, and German Creek Coal Measures (Blenheim Subgroup). The most widespread and commercially important are the coal measures of the Blackwater Group (previously known as the Upper Bowen Coal Measures), which have different names in different areas.

Steaming coal is being produced from the Blair Athol and Collinsville Coal Measures and first units of the Northern Electric Authority's Collinsville power scheme have been commissioned. Metallurgical coking coal is being mined extensively from the Moura, Baralaba, and Rangal Measures in the Blackwater Group, mainly for export to Japan.

Mesozoic

Coal has been produced from the Jurassic Injune Coal Measures and the Cretaceous of the Styx Coalfield. King (1968) and King & Goscombe (1968) have recently given a comprehensive account of the occurrence of coal, the type, resources, and production.

Oil and Gas

In the search for petroleum extensive seismic surveys have been made in the south, and much drilling has been done, especially in the central and southern part of the Denison Trough.

Adequate source rocks and reservoirs, and suitable structures, seem to be present, but no commercial quantities of oil or gas have been found to date.

Nebo Synclinorium

The Permian sediments in the Nebo Synclinorium contain thick marine sequences with coal measures in places. Although folded, the detailed structure is poorly known, and a large part of the synclinorium is masked by superficial deposits. Most of the sequence lacks porosity and post-Permian intrusion makes much of the area unfavourable for the accumulation of oil and gas.

To the west the prospects may be more favourable, especially if the quartz sands of the Collinsville Shelf extend eastwards into the synclinorium.

Collinsville Shelf

The marine sequence on the Collinsville Shelf is considerably thinner than to the east, and the quartz sands are exposed or have only a thin cover. The junction of the shelf with the Nebo Synclinorium, where any sands present will be more deeply buried and capped by the Blackwater Group, may represent a more favourable area. The Collinsville Coal Measures are of moderate rank, and any oil and gas present may still be preserved.

Capella Shelf and Comet Ridge

The oil potential on the Capella Shelf and Comet Ridge is similar to that on the Collinsville Shelf, except that the Comet Ridge is bounded by troughs both to the east and west. The Comet Ridge, however, was apparently considerably more extensive, and formed a platform during the early part of the Permian marine sedimentation. The development of the Mimosa Syncline in this platform may have considerably affected the migration of oil and gas.

Folded Zone

The sequence in the Folded Zone is similar to that in the Nebo Synclinorium, but the intense faulting and tight folding make this an unfavourable area. The presence of anthracite at Bluff is a further unfavourable indication.

Mimosa Syncline

Although the middle part of the marine sequence found to the north and west is not present in the Mimosa Syncline, the marine rocks are thick enough to form a favourable source. Porous rocks are even less well developed than in the Nebo Synclinorium, and the prospects are not good. Hydrocarbons may have migrated westwards into the porous sands associated with the Comet Ridge and the eastern part of the Denison Trough. The few wells drilled, however, have not revealed useful quantities of oil and gas.

Denison Trough

The amount of drilling in the Denison Trough indicates that it has been regarded as an area with good prospects. Porous sands are interbedded with and grade laterally into a thick marine sequence, and favourable structures have been formed by moderate folding. The results to date have been disappointing.

Gold

Gold production has been important. The Clermont area was one of the main alluvial producers in Queensland, and the Golden Plateau mine near Cracow has been one of the few important producers in recent years. Gold has also been produced from the Lady Norman mine near Eungella, Mount Britton, Mount Coolon, Mount Flora, Mount Wyatt, Normanby, near Sarina, Yatton, and from the deep leads on the Rutherford Table. Most of the gold is associated with granitic or dioritic intrusions.

At Clermont reef gold has been relatively unimportant, and the main production has come from Permian deep leads and Tertiary(?) and Recent alluvial deposits. Near Cracow production is from a gold-silver alloy in a quartz gangue in the Camboon Andesite, close to the contact with the Auburn Complex.

Copper

The first significant production of copper in Queensland came from the Peak Downs Copper Beds near Clermont. Between 1862 and 1877 (when the mine was closed) 100,000 tons of ore averaging 17 percent copper were mined. Copper has also been mined at Mount Flora and on the Sellheim River near Mount Wyatt.

Other Metals and Minerals

Other metals and minerals produced commercially include silver (usually in association with other metal ores), bismuth, arsenic, lead, wolfram, molybdenite, nickel, and chromite, but only silver has been produced in important quantities. The Cracow Goldfield with the Golden Plateau mine as its major producer, yielded more than a quarter of a million ounces of silver.

Sapphire

Valuable sapphires have been produced in the Anakie Field. The sapphires are found as waterworn fragments derived from the weathering of Tertiary basalt plugs and possibly from flows. The total estimated value of the rough sapphires produced is $1,410,956. The stones are mostly blue, green, yellow, orange-yellow, and white. A few diamonds have also been found on this field.

Chrysoprase

Chrysoprase of gemstone quality occur as veins in the laterite profile on the serpentinite near Marlborough (Brooks, 1964). Since 1963, several tons mined from shallow pits have been exported, mainly to Germany and the USA.

Graphite has been mined at Jacks Creek, near Collinsville, and small amounts of magnesite have been produced.

Deposits of bentonite, diatomite, and phosphate have been found, but not produced commercially.

BIBLIOGRAPHY

An attempt has been made to include all published references on the Bowen Basin and all readily accessible unpublished papers with the exception of the BMR Petroleum Search Subsidy Acts reports. Unpublished reports on petroleum and mineral exploration are available at the Bureau of Mineral Resources, Canberra, and at the Geological Survey of Queensland, Brisbane.

AERO SERVICE LTD, 1963 - Airborne magnetometer survey over concessions 93P and 94P, Mackay area, Queensland. Report to Ampol Exploration (Qld) Pty Ltd (unpubl.).

ALLEN, R.J., and HOUSTON, B.R., 1964 - Petrology of Mesozoic sandstones of Carnarvon Highway section, Western Bowen and Surat Basins. Geol. Surv. Qld Rep. 6.

ARMAN, M., 1964 - Petrology and correlation of some Permian formations in Planet Warrinilla North No. 1, Queensland. Bur. Miner. Resour. Aust. Rec. 1964/92 (unpubl.).

ARMAN, M., 1965 - Petrographic notes on Bowen Basin shallow holes drilled in 1963. Ibid., 1965/215 (unpubl.).

ARMAN, M., 1965 - Petrography and lithological correlation of Permian formations in AFO Inderi No. 1 and AFO Cooroorah No. 1, Queensland. Ibid., 1965/226 (unpubl.).

AUSTRALIAN OIL AND GAS JOURNAL, 1957 - Arcadia drilling may open up new possibilities. Aust. Oil Gas J., 3(6), 3-7.

ARMSTRONG, J.D., DEAR, J.F., and RUNNEGAR, B., 1967 - Permian ammonoids from eastern Australia. J. geol. Soc. Aust., 14(1), 87-97.

BALL, L.C., 1905 - Central Queensland coal mining industry. Qld Govt Min. J., 6, 14-17.

BALL, L.C., 1905 - Sapphire fields of central Queensland. Notes on their present condition. Ibid., 6, 112-17.

BALL, L.C., 1910 - Field notes on the Mount Flora gold and mineral field. Geol. Surv. Qld Publ. 228.

BALL, L.C., 1910 - Some mineral fields in the hinterland of Mackay, Mount Spencer gold and mineral field, Eungella goldfield, coal at Black Rock Creek. Ibid., 229.

BALL, L.C., 1918 - Simpson's molybdenite find, in the Connor's Range, near Cardowan. Qld Govt Min. J., 19, 304-6.

BALL, L.C., 1918 - Notes on a visit to the central district. Ibid., 19, 306-7.

BALL, L.C., 1918 - A mound spring at Crystalbrook. Ibid., 19, 508-9.

BALL, L.C., 1924 - Report on natural gas at Cockatoo Creek, near Taroom. Ibid., 25, 172-3.

BALL, L.C., 1927 - Report on search for oil - tour in western Queensland with Dr Woolnough. Ibid., 28, 357-8.

BALL, L.C., 1928 - Report on exposures of oil shale in the Dawson River bed. Ibid., 29, 298-9.

BALL, L.C., 1928 - Report on search for oil. Ibid., 29, 394-7.

BALL, L.C., 1928 - Report on a visit to Roma and district. Ibid., 29, 398.

BALL, L.C., 1929 - Position at Roma. Ibid., 30, 389.

BALL, L.C., 1931 - Cracow gold find. Ibid., 32, 308-9.

BALL, L.C., 1945 - Oil shales in Queensland. Ibid., 46, 74-5.

BALME, B.E., 1962 - Some palynological evidence bearing on the development of the Glossopteris-flora; in EVOLUTION OF LIVING ORGANISMS, ed. G.W. Leeper. Melb. Univ. Press, 269-80.

BALME, B.E., 1963 - Plant microfossils from the Lower Triassic of Western Australia. Palaeontology, 6(1), 12-40.

BASTIAN, L.V., 1964 - Petrographic notes on the Peawaddy Formation, Bowen Basin, Queensland. Bur. Miner. Resour. Aust. Rec. 1964/193 (unpubl.).

BASTIAN, L.V., 1965a - Petrological report on the basement to Lower Jurassic sections of some subsidized wells in the Surat Basin. Ibid., 1965/120 (unpubl.).

BASTIAN, L.V., 1965b - Petrographic notes on Permian sandstones of the Springsure 1:250,000 Sheet area, Queensland. Ibid., 1965/230 (unpubl.).

BASTIAN, L.V., 1965c - Petrographic notes on the Clematis sandstone and Moolayember Formation, Bowen Basin, Queensland. Ibid., 1965/240 (unpubl.).

BASTIAN, L.V., 1965d - Petrographic notes on the Rewan Formation, southern Bowen Basin, Queensland. Ibid., 1965/260 (unpubl.).

BASTIAN, L.V., and ARMAN, M., 1965 - Petrographic notes on some Triassic sediments in UKA Wandoan No. 1 and in adjoining areas. Ibid., 1965/227 (unpubl.).

BEASLEY, A.W., 1945 - The petrography of some Queensland oil shales. Mem. Qld Mus., 12(3), 124-33.

BENNETT, F., 1895 - Permo-Carboniferous fossils from Banana. Proc. Roy. Soc. Qld, 11, 47-8.

BOLLEN, L., and GOODEN, J.E., 1963 - Up-grading or iron-ore. AMDL report 228 to Enterprise Exploration Pty Ltd. Geol. Surv. Qld Auth. Rep. 1099 (unpubl.).

BONNER, M.H., 1952 - The 'Klondyke' gold mine, Cracow. Qld Govt Min. J., 53, 57-60.

BOOKER, F.W., 1932 - Appendix to correlations of the Queensland Permo-Carboniferous basin. A new species of Productus from the Lower Bowen Series, Queensland. Proc. Roy. Soc. Qld, 43, 66-72.

BROOKS, J H., 1959 - Golden Plateau mine, Cracow. Qld Govt Min. J., 60, 617-25.

BROOKS, J.H., 1960 - Underground development and exploration, Golden Plateau mine, Cracow, Ibid., 61, 658-61.

BROOKS, J.H., 1964 - Marlborough Creek chrysoprase deposits. Ibid., 65(149), 135-40.

BROOKS, J.H., 1964 - Shepherd's camp gold prospect, GML Appln 511, Cracow. Ibid., 65, 648.

BROOKS, J.H., 1965 - Occurrence of nickel in gabbro at Mt Slopea, north of Taroom. Ibid., 66, 520-1.

BROOKS, J.H., 1965 - Gold deposit of Golden Plateau; in GEOLOGY OF AUSTRALIAN ORE DEPOSITS. 8th Cwealth Min. metall. Cong., Aust. N.Z., 1965, 1, 361-3.

BROWN, D.A., CAMPBELL, K.S.W., and CROOK, K.A.W., 1968 - THE GEOLOGICAL EVOLUTION OF AUSTRALIA AND NEW ZEALAND. Oxford, Pergamon.

BRYAN, W.H., 1925 - Earth movements in Queensland. Proc. Roy. Soc. Qld, 37, 3-82.

BRYAN, W.H., and JONES, O.A., 1946 - The geological history of Queensland: a stratigraphical outline. Univ. Qld Dep. Geol. Pap., 2(12).

BRYAN, W.H., and WHITEHOUSE, F.W., 1926 - Later palaeogeography of Queensland. Proc. Roy. Soc. Qld, 38, 113-14.

BULEY, J.V., 1953 - The Cracow goldfield; in GEOLOGY OF AUSTRALIAN ORE DEPOSITS. 5th Emp. Min. metall. Cong., Aust. N.Z., 1, 817-22.

CAMERON, J.C., 1959 - Hydrodynamics and drape folding. Qld Govt Min. J., 60, 425-8.

CAMERON, W.E., 1903 - Additions to the geology of the Mackay and Bowen districts. Geol. Surv. Qld Publ. 181, 1-21.

CAMERON, W.E., 1905 - Central district coal measures - their continuation towards Mackay and Nebo districts. Qld Govt Min. J., 6, 180, 227.

CAMERON, W.E., 1907 - West Moreton (Ipswich) coalfield. Geol. Surv. Qld Publ. 204.

CAMPBELL, K.S.W., 1953 - The fauna of the Permo-Carboniferous Ingelara Beds of Queensland. Univ. Qld Dep. Geol. Pap., 4(3), 1-30.

CAMPBELL, K.S.W., 1959 - The Martiniopsis-like spiriferids of the Queensland Permian. Palaeontogy, 1, 333-50.

CAMPBELL, K.S.W., 1960 - The brachiopod genera Ingelarella and Notospirifer in the Permian of Queensland. J. Paleont., 34(6), 1106-23.

CAMPBELL, K.S.W., 1961 - New species of the Permian spiriferoids Ingelarella and Notospirifer from Queensland and their stratigraphic implications. Palaeontographica Abt A, 117(5-6), 159-92.

CAMPBELL, K.S.W., 1965 - Australian Permian terebratuloids. Bur. Miner. Resour. Aust. Bull. 68.

CAREY, S.W., and AHMAD, N., 1961 - Glacial marine sedimentation. Proc. 1st int. Symp. on arctic Geology, 2, 865-94.

CLARKE, D.E., PAINE, A.G.L., and JENSEN, A.R., in press - Geology of the Proserpine 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rep. 144.

CLARKE, W.B., 1862 - On the occurrence of Mesozoic and Permian faunae in eastern Australia. Quart. J. geol. Soc. Lond., 18, 244-7.

CLARKE, W.B., 1865 - On the Carboniferous and other geological relations of the Maranoa district in Queensland, in reference to a discovery of zoological fossils in Wollumbilla Creek and Stoney Creek, West Maitland. Trans. Roy. Soc. Vic., 6, 32-42.

CLARKE, W.B., 1867 - On marine fossiliferous Secondary formations in Australia. Quart. J. geol. Soc. Lond., 23, 7-12.

CONDIT, D.D., 1936 - Geological data concerning Roma-Springsure area. Oil Search Ltd Rep. in Geol. Surv. Qld Auth. Rep. 628 (unpubl.).

CONNAH, T.H., 1958 - Summary report, limestone resources of Queensland. Geol. Surv. Qld Publ. 292, 8.

COOKSON, I.C., and DETTMANN, M.E., 1958 - Some trilete spores from Upper Mesozoic deposits in the eastern Australian region. Proc. Roy. Soc. Vic., 70, 95-128.

COOKSON, I.C., and EINSENACK, A., 1958 - Microplankton from Australia and New Guinea Upper Mesozoic sediments. Ibid., 70, 19-78.

CRESPIN, Irene, 1944 - The Hutton Creek bore, Queensland. Bur. Miner. Resour. Aust. Rec. 1944/12 (unpubl.).

CRESPIN, Irene, 1944 - Foraminifera in the Permian rocks of Australia. Ibid., 1944/24 (unpubl.).

CRESPIN, Irene, 1945 - Some Permian Foraminifera from eastern Australia. Proc. Roy. Soc. Qld, 56, 23-30.

CRESPIN, Irene, 1945 - Permian Ostracoda from eastern Australia. Ibid., 56, 31-6.

CRESPIN, Irene, 1945 - The Hutton Creek bore, Queensland. Bur. Miner. Resour. Aust. Rec. 1945/14. (unpubl.).

CRESPIN, Irene, 1945 - The Arcadia bore, Queensland. Ibid., 1945/15 (unpubl.).

CRESPIN, Irene, 1948 - Report on samples from a cutting approximately 40 miles north of Injune, along the Rolleston Highway, Queensland. Ibid., 1948/74 (unpubl.).

CRESPIN, Irene, 1958 - Permian Foraminifera of Australia. Bur. Miner. Resour. Aust. Bull. 48.

CRIBB, H.G.S., McTAGGART, N.R., and STAINES, H.R.E., 1960 - Sediments east of the Great Divide; in Hill & Denmead, eds. J. geol. Soc. Aust., 7, 345-55.

CROLL, I.C.H., 1950 - The opal industry in Australia. Bur. Miner. Resour. Aust. Bull. 17.

CROOK, K.A.W., 1960 - Classification of arenite. Amer. J. Sci., 258, 419-28.

CUNDILL, J., and MEYERS, N., 1964 - A discussion of the Permian geology in the area of the Planet Warrinilla and Warrinilla North wells. APEA J., 1964, 133-49.

DAINTREE, R., 1870 - General report upon the northern district. Qld parl. Pap.

DAINTREE, R., 1872 - Notes on the geology of the Colony of Queensland. Quart. J. geol. Soc. Lond., 28, 271-317.

DARBY, F., 1966 - North Bowen Basin reconnaissance gravity survey, central Queensland, 1963. Bur. Miner. Resour. Aust. Rec. 1966/209 (unpubl.).

DAVID, T.W.E., 1932 - Explanatory notes to accompany a new geological map of the Commonwealth of Australia. Counc. sci. ind. Res. Aust.

DAVID, T.W.E., ed W.R. BROWNE, 1950 - THE GEOLOGY OF THE COMMONWEALTH OF AUSTRALIA. 3 vols. London, Arnold.

DAY, R.W., 1964 - Stratigraphy of the Roma-Wallumbilla area. Geol. Surv. Qld Publ. 318.

DEAR, J.F., 1968 - Geology of the Cania district. Geol. Surv. Qld Publ. 330.

DEAR, J.F., and JENSEN, A.R., 1965 - Geological notes on the eastern rim of the Surat-Bowen Basin. Geol. Soc. Aust. Qld Div., 1965 Field Conf. Hdbk., 5-10.

DEAR, J.F., McKELLAR, R.G., and TUCKER, R.M., in press - Geology of the Monto 1:250,000 Sheet area. Geol. Surv. Qld Rep. 46.

DE JERSEY, N.J., 1946 - Microspore types in some Queensland Permian coals. Univ. Qld Dep. Geol. Pap., n.s., 3(5).

DE JERSEY, N.J., 1955 - Microscope correlation, Styx coalfield. Geol. Surv. Qld Publ. 281, appendix I.

DE JERSEY, N.J., 1965 - Plant microfossils in some Queensland crude oil samples. Ibid., 329.

DE JERSEY, N.J., and PATEN, R.J., 1963 - The palynology of samples from UKA Moonie Nos 1 and 3 wells. Geol. Surv. Qld Rec. 1963/1 (unpubl.).

DE JERSEY, N.J., and PATEN, R.J, 1963 - The palynology of samples from UKA Yarrill Creek No. 1 well. Ibid., 1963/3 (unpubl.).

DE JERSEY, N.J., and PATEN, R.J., 1964 - Jurassic spores and pollen grains from the Surat Basin. Geol. Surv. Qld Publ. 322.

DENMEAD, A.K., 1931 - New gold discoveries on Cracow holding. Qld Govt Min. J., 32, 307-8.

DENMEAD, A.K., 1931 - The Cracow gold discovery. Supplementary report. Ibid., 32, 355-8.

DENMEAD, A.K., 1932 - The Cracow goldfield. Report on operations during the past sixteen months. Ibid., 33, 369-76.

DENMEAD, A.K., 1933 - Recent development at Cracow. Ibid., 34, 196-9, 237-9.

DENMEAD, A.K., 1937 - Cracow ore reserves. Ibid., 38, 121-5.

DENMEAD, A.K., 1938 - The Cracow goldfield. Ibid., 39, 262-3, 335-40, 368-76, 406-12.

DENMEAD, A.K., 1939 - Cracow goldfield - four plans to accompany report. Ibid., 40, 14.

DENMEAD, A.K., 1943 - Carnarvon oil shale. Ibid., 44(504), 70-1.

DENMEAD, A.K., 1946 - Notes on Cracow goldfield. Ibid., 47, 306-11.

DND [Department of National Development, Canberra], 1965-68 - Fitzroy region, Queensland, resources series - Map sheets and booklets: surface water, 1965; roads and aerodromes, 1965; climate, 1965; population and selected services, 1966; geology, 1966; railways and ports, 1966; land-forms, 1967a; minerals and mining, 1967b; soils, 1967c; land tenure 1967d; rural production, 1968; underground water, in prep.

DERRINGTON, S.S., 1957 - AAO No. 7 (Arcadia) well. Completion Rep. (unpubl.).

DERRINGTON, S.S., 1962 - The tectonic framework of the Bowen Basin. Aust. Oil Gas J., 8(4), 26-9, also in APEA, 1961 Conf. Paps, 18-21, 1962.

DERRINGTON, S.S., GLOVER, J.J.E., and MORGAN, K.H., 1959 - New names in Queensland stratigraphy. Permian of the south-eastern part of the Bowen syncline. Aust. Oil Gas J., 5(8), 27-35.

DEVINE, S.B., and POWER, P.E., 1967 - Permian stratigraphic revisions and rock unit correlations, central western Bowen Basin, Queensland. Qld Govt Min. J., 68, 511-20.

DICKINS, J.M., 1961 - Permian pelecypods newly recorded from eastern Australia. Palaeontology, 4(1), 119-30.

DICKINS, J.M., 1963 - Permian pelecypods and gastropods from Western Australia. Bur. Miner. Resour. Aust. Bull. 63.

DICKINS, J.M., 1969 - Correlation of the Permian of the Hunter Valley, New South Wales, and the Bowen Basin, Queensland. Ibid., 80, 27-44.

DICKINS, J.M., (in press) - Correlation and subdivision of the Permian of eastern and western Australia. Proc. 22nd int. geol. Cong., New Delhi, 1964. Reprinted in Bur. Miner. Resour. Aust. Bull. 116, 17-27, 1970.

DICKINS, J.M., and MALONE, E.J., 1968 - Regional subdivision of the Back Creek Group (Middle Bowen Beds), Bowen Basin, Queensland. Qld Govt Min. J., 69(801), 292-301.

DICKINS, J.M., MALONE, E.J., and JENSEN, A.R., 1964 - Subdivision and correlation of the Middle Bowen Beds. Bur. Miner. Resour. Aust. Rep. 70.

DUNSTAN, B., 1898 - The geology of Collaroy and Carmila. Geol. Surv. Qld Publ. 141.

DUNSTAN, B., 1900 - The coal measures of the Dawson River; in Annual progress report of the Geological Survey for the year 1899. Ibid., 150, 13.

DUNSTAN, B., 1900 - Clermont coal measures Pt I. Qld Govt Min. J., 1, 244-8.

DUNSTAN, B., 1900 - Clermont coal measures Pt II. Ibid., 1, 288-92.

DUNSTAN, B., 1900 - Permo-Carboniferous coal measures of Clermont and associated formations. Geol. Surv. Qld Publ. 148.

DUNSTAN, B., 1901 - The geology of the Dawson and Mackenzie Rivers with special reference to the occurrence of anthracite coal. Ibid., 155, 1-28, and Qld Govt Min. J., 2, 118-22, 162-70, 212-16.

DUNSTAN, B., 1901 - Notes on fossil fish at Duaringa, Central Railway line. Ann. Progress Rep. geol. Surv. Qld 1900, 192-3.

DUNSTAN, B., 1902 - The sapphire fields of Anakie. Geol. Surv. Qld Publ. 172, 1-26.

DUNSTAN, B., 1902 - The sapphire fields of Anakie; in Annual progress report of the Geological Survey for the year 1901. Ibid., 175, 9.

DUNSTAN, B., 1902 - The Clermont gold field; in Annual progress report of the Geological Survey for the year 1901. Ibid., 175, 11.

DUNSTAN, B., 1902 - The Clermont gold field. Ibid., 176, 1-34.

DUNSTAN, B., 1904 - Notes on asbestos in the Rockhampton district. Qld Govt Min. J., 5, 161.

DUNSTAN, B., 1912 - Bowen River coal deposits. Ibid., 13, 485.

DUNSTAN, B., 1913 - Bowen River coal deposits. Ibid., 14, 648-9.

DUNSTAN, B., 1913 - The coal resources of Queensland; in THE COAL RESOURCES OF THE WORLD. An inquiry made upon the initiative of the executive committee of the 12th int. geol. Cong., Canada, 1, 17-39.

DUNSTAN, B., 1913 - Coal resources of Queensland. (A general review). Geol. Surv. Qld Publ. 239.

DUNSTAN, B., 1913 - Queensland mineral index and guide. Ibid., 241.

DUNSTAN, B., 1916 - Queensland mineral deposits. 3 - Asbestos. Qld Govt Min. J., 17, 372-6.

DUNSTAN, B., 1916 - Styx River coalfield. Ibid., 17, 124.

DUNSTAN, B., 1917 - The Bowen River and other coalfields. Ibid., 18, 88.

DUNSTAN, B., 1919 - Terra-cotta clays and asbestos in Queensland (Dalcalmah, near Marlborough). Ibid., 20, 345.

DUNSTAN, B., 1920 - Asbestos - Article 2 in Industrial Minerals. Geol. Surv. Qld Publ. 268(1).

EAST, J.D., 1947 - Miclere field - Clermont. Qld Govt Min. J., 48, 17-19.

ETHERIDGE, R., 1872 - Description of the Palaeozoic and Mesozoic fossils of Queensland. Quart. J. geol. Soc. Lond., 28, 317-60.

ETHERIDGE, R., Jnr, 1880 - Report on a collection of fossils from the Bowen River coalfields and the limestone of the Fanning River, north Queensland. Proc. Roy. phys. Soc. Edinb., 5, 263-328.

ETHERIDGE, R., Jnr, 1883 - Further remarks on Australian Strophalosiae; and description of a new species of Aucella, from the Cretaceous rocks of north-east Australia. J. Roy. Soc. N.S.W., 17, 87-92.

ETHERIDGE, R., Jnr, 1911 - The Lower Palaeozoic corals of Chillagoe and Clermont. Geol. Surv. Qld Publ. 231.

EVANS, P.R., 1962 - Microfossils associated with the 'Bundamba Group' of the Surat Basin, Queensland. Bur. Miner. Resour. Aust. Rec. 1962/115 (unpubl.).

EVANS, P.R., 1963 - Spore preservation in the Bowen Basin. Ibid., 1963/100 (unpubl.).

EVANS, P.R., 1964a - Some palynological observations of the Mesozoic of the Baralaba, Monto, Taroom and Mundubbera 1:250,000 Sheet areas, Bowen-Surat Basin. Ibid., 1964/91 (unpubl.).

EVANS, P.R., 1964b - Palynological observations on Union-Kern-AOG Cabawin East No. 1 well. Bur. Miner. Resour. Aust. Petrol. Search Subs. Acts Publ. 44.

EVANS, P.R., 1964c - The age of the Precipice Sandstone. Aust. J. Sci., 26(10), 323.

EVANS, P.R., 1964d - A correlation of some deep wells in the north-eastern Eromanga Basin, central Queensland. Bur. Miner. Resour. Aust. Rec. 1964/197 (unpubl.).

EVANS, P.R., 1965 - Recent advances in Mesozoic stratigraphic palynology in Australia. Ibid., 1965/192 (unpubl.).

EVANS, P.R., 1966a - Mesozoic stratigraphic palynology in Australia. Aust. Oil Gas J., 12, 6.

EVANS, P.R., 1966b - Palynological studies in the Longreach, Jericho, Galilee, Tambo, Eddystone and Taroom 1:250,000 Sheet areas, Queensland. Bur. Miner. Resour. Aust. Rec. 1966/61 (unpubl.).

EVANS, P.R., 1966c - Contributions to the palynology of the Permian and Triassic of the Bowen Basin. Ibid., 1966/134 (unpubl.).

EVANS, P.R., 1969 - Upper Carboniferous and Permian palynological stages and their distribution in eastern Australia. Proc. 1st int. Symposium on Gondwana Palaeontology and Stratigraphy, Mar Del Plata, Argentina, 1967.

EVANS, P.R., and HODGSON, E.A., 1965 - Palynological correlation of Planet Tooloombilla No. 1, Crystalbrook No. 1 and Warrong No. 1, Eddystone 1:250,000 Sheet area, Surat Basin, Queensland. Bur. Miner. Resour. Aust. Rec. 1965/88 (unpubl.).

EXON, N.F., 1966 - Revised Jurassic to Lower Cretaceous stratigraphy in the south-east Eromanga Basin, Queensland. Qld Govt Min. J., 67(5), 232-8.

EXON, N.F., 1968 - Eddystone, Qld - 1:250,000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes SG/55-7.

EXON, N.F., GALLOWAY, M.C., and CASEY, D.J., 1966 - The geology of the northern half of the Mitchell 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rec. 1966/90. (unpubl.).

EXON, N.F., GALLOWAY, M.C., CASEY, D.J., and KIRKEGAARD, A.G., in prep. - Geology of the Tambo/Augathella area, Queensland. Bur. Miner. Resour. Aust. Rep. 143.

FEISTMANTEL, O., 1890 - Geological and palaeontological relations of the coal and plant-bearing beds of Palaeozoic and Mesozoic age in eastern Australia and Tasmania. Mem. geol. Surv. N.S.W., Palaeont., 3.

FEHR, A., 1962 - Petrology of surface samples from the Springsure area and the north-eastern Bowen Basin. Inst. franc. Petrole Mission in Australia Rep. Aust./61 (unpubl.).

FEHR, A., 1965 - Lithological study of Triassic and Lower Jurassic units in seven wells in the southern Bowen-Surat Basin. Bur. Miner. Resour. Aust. Rec. 1965/175 (unpubl.).

FEHR, A., and BASTIAN, L.V., 1962 - Petrological report on the Cabawin No. 1 well, Bowen-Surat Basin, Queensland. Inst. franc. Petrole Mission in Australia Rep. Aust./52 (unpubl.).

FLETCHER, H.O., 1947 - A brief suggested correlation between the Permian sequence of the Hunter Valley of New South Wales and the Springsure section of Queensland. Aust. Ass. Adv. Sci. Rep., 25, 354-6.

FORBES, V.R., 1968 - Taroom, Qld - 1:250,000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes SG/55-8.

GEOLOGICAL SURVEY OF QUEENSLAND, 1951 - Queensland coalfields. A summary of data. Qld Govt Min. J., 52, 624-32.

GEOLOGICAL SURVEY OF QUEENSLAND, 1955 - Coal resources Tooloombah Creek area, Styx coalfield. Geol. Surv. Qld Publ. 281.

GEOLOGICAL SURVEY OF QUEENSLAND, 1960 - Occurrence of petroleum and natural gas in Queensland (with supplements 1-5, 1961-1966). Ibid., 299.

GEOLOGICAL SURVEY OF QUEENSLAND, 1965 - Monto 1:250,000 Geological Sheet, preliminary edition.

GERRARD, M.J., 1964 - Amoseas Westbourne No. 1 well. Completion Rep. (unpubl.).

GUNN, R.H., GALLOWAY, R.W., PEDLEY, L., and FITZPATRICK, E.A., 1967 - Lands of the Nogoa-Belyando area, Queensland. Sci. ind. Res. Org., Land Res. Ser., 10.

HAHN, G.W., and FISHER, N.H., 1963 - Review of the available groundwater data on the Great Artesian Basin. Bur. Miner. Resour. Aust. Rec. 1963/128 (unpubl.).

HAWTHORNE, W.L., 1961 - Coal resources Nebo coalfield, diamond drilling of the Elphinstone seam. Geol. Surv. Qld Publ. 303.

HILL, D., 1939 - The Middle Devonian rugose corals of Queensland. I. Douglas Creek and Drummond Creek, Clermont district. Proc. Roy. Soc. Qld, 50, 55-65.

HILL, D., 1943 - A re-interpretation of the Australian Palaeozoic record based on a study of rugose corals. Ibid., 54, 53-66.

HILL, D., 1950 - The Productinae of the Artinskian Cracow fauna of Queensland. Pap. Univ. Qld Dep. Geol., 3(2), 1-27.

HILL, D., 1951 - Geology; in HANDBOOK OF QUEENSLAND. Aust. Ass. Adv. Sci., Brisbane, 13-24.

HILL, D., 1952 - The Gondwana System in Queensland; in Symposium sur les series de Gondwana. 19ieme Cong. geol. int., Alger, 35-49.

HILL, D., ed., 1953 - The geological map of Queensland. Qld Dep. Mines.

HILL, D., 1957 - Explanatory notes on the Springsure 4-mile Geological Sheet. Bur. Miner. Resour. Aust. Note Ser. 5.

HILL, D., and DENMEAD, A.K., eds, 1960 - THE GEOLOGY OF QUEENSLAND. J. geol. Soc. Aust., 7.

HILLS, E.S., 1934 - Tertiary freshwater fishes from southern Queensland. Mem. Qld Mus., 10(4), 157-74.

HILLS, E.S., 1943 - Tertiary freshwater fishes and crocodilian remains from Gladstone and Duaringa, Queensland. Ibid., 12(2), 96-100.

ISBELL, R.F., 1954 - An investigation of the Callide, Don and Dee Valleys. Qld Bur. Invest. Tech. Bull. 3.

ISBELL, R.F., 1954 - Survey of the Nebo-Collinsville region. Ibid., 4.

ISBELL, R.F., 1955 - The geology of the northern section of the Bowen Basin. Univ. Qld Dep. Geol. Pap., 4(11).

ISBELL, R.F., 1957 - Soil association map; Dawson Valley region, Queensland. Qld Bur. Invest. Ann. Rep.

JACK, R.L., 1879a - The Bowen River coalfield. Geol. Surv. Qld Publ. 3.

JACK, R.L., 1879b - On the Bowen River coalfield. Ibid., 4.

JACK, R.L., 1887 - The geological features of the Mackay district. Ibid., 39.

JACK, R.L., 1888 - The mineral wealth of Queensland. Ibid., 48.

JACK, R.L., 1889 - On the Sellheim silver mines and surrounding district. Ibid., 57.

JACK, R.L., 1895a - Annual progress report of the Geological Survey for the year 1894. Artesian water in the western interior of Queensland. Geol. Surv. Qld Bull. 1, also Geol. Surv. Qld Publ. 103.

JACK, R.L., 1895b - Report of the government geologist; in Annual progress report of the Geological Survey for the year 1894. Geol. Surv. Qld Publ. 103.

JACK, R.L., 1899 - Annual progress reports of the Geological Survey for the years 1896-98 (Clermont - Deep Lead). Ibid., 143, 10-11.

JACK, R.L., and ETHERIDGE, R., 1892 - The geology and palaeontology of Queensland and New Guinea. Ibid., 92, and London, Dulau.

JARDINE, F., 1928 - The Broadsound drainage in relation to the Fitzroy River. Rep. Gt Barrier Reef Comm., 2, 89-92.

JENSEN, A.R., 1963 - Geology of the southern half of the Proserpine 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rec. 1953/65 (unpubl.).

JENSEN, A.R., 1965 - Mackay, Qld - 1:250,000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes SF/55-8.

JENSEN, A.R., 1968 - Upper Permian and Lower Triassic sedimentation of part of the Bowen Basin, Queensland. Bur. Miner. Resour. Aust. Rec. 1968/55 (unpubl.).

JENSEN, A.R., and ARMAN, M., 1966 - Notes on some Upper Permian and Lower Triassic units of the Bowen Basin, Queensland. Ibid., 1966/21 (unpubl.).

JENSEN, A.R., GREGORY, C.M., and FORBES, V.R., 1964 - The geology of the Taroom 1:250,000 Sheet area and the western part of the Mundubbera 1:250,000 Sheet area. Ibid., 1964/61 (unpubl.).

JENSEN, A.R., GREGORY, C.M., and FORBES, V.R., 1966 - Geology of the Mackay 1:250,000 Sheet area Queensland. Bur. Miner. Resour. Aust. Rep. 104.

JENSEN, H.I., 1921a - The geology of the country north of Roma. Qld Govt Min. J., 22, 92-3.

JENSEN, H.I., 1921b - The geology and mineral resources of the Carnarvon district. Condensed preliminary report. Ibid., 22, 401-6.

JENSEN, H.I., 1921c - Geology of the Mount Coolon district. Ibid., 22, 491-5.

JENSEN, H.I., 1922 - The Tambo and Barcaldine districts: supposed oil manifestations of the Enniskillen Range. Ibid., 23, 157-9, 185-8.

JENSEN, H.I., 1922 - The oil prospects in the Lower Walloon strata of western Queensland. Ibid., 23, 226-7.

JENSEN, H.I., 1922 - Oil prospects at Hutton Creek. Ibid., 23, 288.

JENSEN, H.I., 1923 - Some notes on the Permo-Carboniferous and overlying Systems in central Queensland. Proc. Linn. Soc. N.S.W., 48(2), 153-8.

JENSEN, H.I., 1923 - Summary of coal investigations and diamond drilling for coal at Injune Creek. Qld Govt Min. J., 24, 14-16.

JENSEN, H.I., 1925 - Palaeogeography of Queensland. Ibid., 26, 379-82, 422-4, 459-64.

JENSEN, H.I., 1926a - Geological reconnaissance between Roma, Springsure, Tambo and Taroom. Geol. Surv. Qld Publ. 277.

JENSEN, H.I., 1926b - Oil possibilities in Queensland. Qld Govt Min. J., 27, 12-19, 48-52.

JENSEN, H.I., 1929 - Walloon Series north of Roma. Ibid., 30, 282-3.

JENSEN, H.I., 1960 - Geology and oil indications of the Roma district. Qld Geogr. J., 60, 13-20.

JENSEN, H.I., 1963 - Geological sequence in the early bores in the Roma district. Ibid., 61, 18.

JEWELL, F., 1963 - Arcadia (AAO No. 7) well logging, Queensland, 1957. Bur. Miner. Resour. Aust. Rec. 1963/16 (unpubl.).

JONES, O.A., 1932 - A revision of the Australian species of the coral genera Spongophyllum E. and H. and Endophyllum E. and H. with a note on Aphrophyllum Smith. Proc. Roy. Soc. Qld, 44, 50-63.

JONES, O.A., 1941 - The Devonian Tabulata of Douglas and Drummond Creeks, Clermont, Queensland. Ibid., 53, 41-60.

JONES, O.A., 1948 - Ore genesis in Queensland. Ibid., 59, 1-91.

JONES, O.A., 1948 - Triassic plants from Cracow. Ibid., 59, 101-8.

KAULBACK, J.A., 1965 - An appraisal of the phosphate prospects of the Bowen Basin. Bur. Miner. Resour. Aust. Rec. 1965/57 (unpubl.).

KING, D., 1968 - Coal resources of central Queensland. Qld Govt Min. J., 69(799), 203-12.

KING, D., and GOSCOMBE, P.W., 1968 - Coal geology of the Bowen Basin. Ibid., 69(805), 493-9.

KIRKEGAARD, A.G., 1970 - Duaringa, Qld - 1:250,000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes SF/55-16.

KIRKEGAARD, A.G., SHAW, R., and MURRAY, C.G., 1966 - Geology of the Rockhampton and Port Clinton 1:250,000 Sheet areas, Queensland. Geol. Surv. Qld Rec. 1966/1 (unpubl.), and Geol. Surv. Qld Publ. (in prep.).

KISCH, J., 1966 - Chlorite-illite tonstein in high rank coals from Queensland, Australia. Amer. J. Sci., 264, 386-97.

LEICHHARDT, F.W.L., 1847 - JOURNAL OF AN OVERLAND EXPEDITION IN AUSTRALIA FROM MORETON BAY TO PORT ESSINGTON - A DISTANCE OF UPWARDS OF 3,000 MILES DURING THE YEARS 1844-1845. London, Boone.

LEVINGSTON, K.R., 1953 - 'Graphite Consolidated' mine, Collinsville. Qld Govt Min. J., 54, 50-2.

LEVINGSTON, K.R., 1953 - Ukalunda Gold Mining Syndicate, Ukalunda. Ibid., 54, 818-23.

LINDNER, A.W., 1966 - Pre-Jurassic basins in north central Queensland. APEA, 1966 Conf. Paps.

LINDON, E.B., 1887 - A catalogue of such minerals as are at present known in Queensland, with their principal associations and places of occurrence. Proc. Roy. Soc. Qld, 4, 32-78.

LLOYD, A.R., 1962 - Foraminifera from AAO Westgrove No. 1 well, Queensland. Bur. Miner. Resour. Aust. Rec. 1962/189 (unpubl.).

LONSDALE, G.F., 1965 - Southern Queensland contract reconnaissance gravity survey using helicopters, 1964. Bur. Miner. Resour. Aust. Rec. 1965/251 (unpubl.).

McANDREW, J., 1955 - Hydromica in sandstone from Styx coalfield Queensland; in Stillwell, F.L. App. 2. Coal Resources Tooloombah Creek area, Styx coalfield. Geol. Surv. Qld Publ. 281, 14-15.

MACK, J.E., Jnr, 1963 - Reconnaissance geology of the Surat Basin. Queensland and New South Wales. Bur. Miner. Resour. Aust. Petrol. Search Subs. Acts Publ. 40.

McLEOD, I.R., 1965 - Australian mineral industry: The mineral deposits. Bur. Miner. Resour. Aust. Bull. 72.

McTAGGART, N.R., 1959 - In Groundwater investigations of the property of N.F.H. Knudsen, 'Kilbiggan', Chinchilla. Irrig. Water Supply Comm. Qld, in Geol. Surv. Qld Auth. Rep. 366 (unpubl.).

McTAGGART, N.R., 1963 - Geology of the north-eastern Surat Basin. Aust. Oil Gas J., 9(12), 44.

MACKENZIE, D.E., 1966 - Heavy mineral analysis of Permian sandstone units, Springsure 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rec. 1966/38 (unpubl.).

MAITLAND, A.G., 1889 - Geological observations at the heads of the Isaacs, the Suttor and the Bowen Rivers. Geol. Surv. Qld Publ. 54, 1-6.

MAITLAND, A.G., 1890 - Annual progress report of the Geological Survey for the year 1889. Mackay district and heads of Isaacs, Suttor and Bowen Rivers. Ibid., 58, 11-14.

MAITLAND, A.G., 1895 - Proposed boring for coal on the Central Railway. Ibid., 107.

MALONE, E.J., 1963 - Bowen Basin shallow drilling and coring programme 1963. Bur. Miner. Resour. Aust. Rec. 1963/153. (unpubl.).

MALONE, E.J., 1964a - Correlation of Permian-Lower Triassic sediments, Springsure-Purbrook area, Queensland. Ibid., 1964/87 (unpubl.).

MALONE, E.J., 1964b - Depositional evolution of the Bowen Basin. J. geol. Soc. Aust., 11(2), 263-82.

MALONE, E.J., 1966 - Fitzroy Region, Queensland, resources series: Geology, map sheet and booklet. Resources, Information and Development Branch Department of National Development, Canberra.

MALONE, E.J., 1968 - Mount Coolon, Qld - 1:250,000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes SF/55-7.

MALONE, E.J., and BASTIAN, L.V., 1964 - Additions to the geology of the Duaringa and Saint Lawrence 1:250,000 Sheet areas, Queensland. Bur. Miner. Resour. Aust. Rec. 1964/108 (unpubl.).

MALONE, E.J., CORBETT, D.W.P., and JENSEN, A.R., 1964 - The geology of the Mt Coolon 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Rep. 64.

MALONE, E.J., JENSEN, A.R., GREGORY, C.M., and FORBES, V.R., 1966 - Geology of the southern half of the Bowen 1:250,000 Sheet area, Queensland. Ibid., 100.

MALONE, E.J., MOLLAN, R.G., OLGERS, F., JENSEN, A.R., GREGORY, C.M., KIRKEGAARD, A.G., and FORBES, V.R., 1963 - Geology of the Duaringa and Saint Lawrence 1:250,000 Sheet areas, Queensland. Bur. Miner. Resour. Aust. Rec. 1963/60.

MALONE, E.J., OLGERS, F., and KIRKEGAARD, A.G., 1969 - The geology of the Duaringa and Saint Lawrence 1:250,000 Sheet areas, Queensland. Bur. Miner. Resour. Aust. Rep. 121.

MARATHON [Petroleum Australia Ltd], 1963 - Bauhinia Downs-Mimosa reflection seismograph survey, ATP 89P, Queensland, Australia.

MARSHALL, C.E., and NARAIN, N., 1954 - Regional gravity investigations in the eastern and central Commonwealth. Mem. Dep. Geol. Geophys. Univ. Sydney, 1954/2.

MAXWELL, W.G.H., 1954 - Strophalosia in the Permian of Queensland. J. Paleont., 28, 533-59.

MOLLAN, R.G., 1965 - Tertiary volcanics in the Peak Range, central Queensland. Bur. Miner. Resour. Aust. Rec. 1965/241 (unpubl.).

MOLLAN, R.G., 1967 - Springsure, Qld - 1:250,000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes SG/55-3.

MOLLAN, R.G., DICKINS, J.M., EXON, N.F., and KIRKEGAARD, A.G., 1969 - Geology of the Springsure 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rep. 123.

MOLLAN, R.G., EXON, N.F., and FORBES, V.R., 1965 - Notes on the geology of the Eddystone 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rec. 1965/98.

MOLLAN, R.G., EXON, N.F., and FORBES, V.R., 1965 - Shallow stratigraphic drilling, Bowen and Great Artesian Basins 1964. Ibid., 1965/119 (unpubl.).

MOLLAN, R.G. FORBES, V.R., JENSEN, A.R., EXON, N.F., and GREGORY, C.M., in press - Geology of the Eddystone, Taroom, and western part of the Mundubbera Sheet areas, Queensland. Bur. Miner. Resour. Aust. Rep. 142.

MOLLAN, R.G., KIRKEGAARD, A.G., EXON, N.F., and DICKINS, J.M., 1964 - Note on the Permian rocks of the Springsure area and proposal of a new name, Peawaddy Formation. Qld Govt Min. J., 65, 576-81.

MORAN, W.R., and GUSSOW, W.C., 1963 - The history of the discovery and the geology of the Moonie oilfield, Queensland, Australia. Geological section, in Moonie and the Surat Basin. Aust Oil Gas J., 10(2), 44.

MORTON, A.G., and MOSS, F.J., 1961 - Cooroorah Anticline seismic refraction survey, Queensland, 1959. Bur. Miner. Resour. Aust. Rec. 1961/107 (unpubl.).

MORTON, C.C., 1922 - Reported occurrence of petroleum on Nogoa Downs, Emerald district. Qld Govt Min. J., 23, 225-6.

MORTON, C.C., 1932 - Mount Clifford workings, Anakie, central Queensland. Ibid., 33, 136-9.

MORTON, C.C., 1935 - The Mt Coolon goldfield. Ibid., 36, 196-200, 232-7.

MORTON, C.C., ed, 1955 - Coal resources, Tooloombah Creek area, Styx coalfield. Geol. Surv. Qld Publ. 281, 1-36.

MOTT, W.D., 1952 - Oil in Queensland. Qld Govt Min. J., 53, 848.

NEUMANN, F.J.G., 1959 - Report on a gravity survey at the Blair Athol coalfield, Queensland. Bur. Miner. Resour. Aust. Rec. 1959/143 (unpubl.).

OAKES, B.P., RAYNER, J.M., and NYE, P.B., 1938 - Geophysical report on the area south-east of Mt Coolon gold mine. Aer. Surv. N. Aust. Qld Rep. 36.

OLDHAM, W.H., 1958 - Semi-detailed gravity survey in the Comet-Rolleston area, Queensland. Bur. Miner. Resour. Aust. Rec. 1958/10 (unpubl.).

OLGERS, F., 1966 - Baralaba, Qld - 1:250,000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes SG/55-4.

OLGERS, F., 1969a - Clermont, Qld - 1:250,000 Geological Series. Ibid., SF/55-11.

OLGERS, F., 1969b - Emerald, Qld - 1:250,000 Geological Series. Ibid., SF/55-15.

OLGERS, F., in prep. - Geology of the Drummond Basin, Queensland. Bur. Miner. Resour. Aust. Bull. 132.

OLGERS, F., DOUTCH, H.F., and EFTEKHARNEZHAD, J., 1967 - Progress report on the geology of the Drummond Basin, Queensland. Bur. Miner. Resour. Aust. Rec. 1967/153 (unpubl.).

OLGERS, F., WEBB, A.W., SMIT, J.A.J., and COXHEAD, B.A., 1964 - The geology of the Gogango Range, Queensland. Ibid., 1964/55 (unpubl.).

OLGERS, F., WEBB, A.W., SMIT, J.A.J., and COXHEAD, B.A., 1966 - Geology of the Baralaba 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rep. 102.

PAINE, A.G.L., GREGORY, C.M., and CLARKE, D.E., 1970 - Geology of the northern half of the Bowen 1:250,000 Sheet area, Queensland (with additions to the geology of the southern half). Bur. Miner. Resour. Aust. Rec. 1970/50. (unpubl.).

PATEN, R.J., 1964 - The Tertiary geology of Boulia region, western Queensland. Bur. Miner. Resour. Aust. Rep. 77.

PATTERSON, G.W., 1955 - Preliminary review of the geology of the younger Palaeozoic of central Queensland. Aust. Oil Exploration Rep. (unpubl.).

PLUMSTEAD, Edna P., 1962 - Trans-Antarctic Exploration 1953-58, Scientific Reports No. 9, Geology 2. Fossil floras of Antarctica with an appendix on Antarctic fossil wood by Richard Krausel. London, Trans-Antarctic Exploration Committee.

POWELL DUFFRYN TECHNICAL SERVICES, 1949 - First reports on the coal industry of Queensland. 3 vols. Qld parl. Pap. A16, 1949.

POWER, P.E., 1966 - Revisions of the Permian stratigraphy of the Denison Trough. Qld Govt Min. J., 67(773), 109-16.

POWER, P.E., 1967 - Geology and hydrocarbons, Denison Trough, Australia. Bull. Amer. Ass. Petrol. Geol., 51(7), 1320-45.

QUEENSLAND DEPARTMENT OF MINES, 1920 - Warden's report - The Styx coalfield - important boring developments. Qld Govt Min. J., 21, 212.

RAGGATT, H.G., and FLETCHER, H.O., 1937 - A contribution to the Permian-Upper Carboniferous problem and an analysis of the fauna of the Upper Palaeozoic (Permian) of North-west Basin, Western Australia. Rec. Aust. Mus., 20, 150-84.

RANDS, W.H., 1886 - Report on the geology and mineral deposits of the country in the vicinity of Clermont. Geol. Surv. Qld Publ. 27.

RANDS, W.H., 1889 - Annual progress report of the Geological Survey for the year 1888. Clermont. Ibid., 49, 6.

RANDS, W.H., 1891 - New discovery of coal near the Callide Creek, Port Curtis district. Ibid., 80.

RANDS, W.H., 1892 - Styx River coalfield. Ibid., 84, 1-10.

RANDS, W.H., 1892 - Annual progress report for the Geological Survey for the year 1891. Coal near Callide Creek. Ibid., 87, 17.

RANDS, W.H., 1894 - Annual progress report for the Geological Survey for the year 1893. (Report of fossils). Ibid., 98, 5.

REEVES, F., 1947 - Geology of the Roma district, Queensland, Australia. Bull. Amer. Ass. Petrol. Geol., 31(8), 1341-71.

REID, J.H., 1921 - Geology of the Walloon-Rosewood coalfield. Qld Govt Min. J., 22, 223-7, 264-70, 310-16, 357-9.

REID, J.H., 1924 - Permo-Carboniferous geology of Queensland - additional notes. Ibid., 25, 46-8.

REID, J.H., 1924-1925 - Geology of the Bowen River coalfield. Ibid., 25, 399-411, 447-66; 26, 4-11.

REID, J.H., 1925 - Permo-Carboniferous coal measures, etc., of the Nebo district. Ibid., 26, 465-74.

REID, J.H., 1927 - Bowen coal - tests on washing and coking. Ibid., 28, 89-91.

REID, J.H., 1928a - The Isaacs River Permo-Carboniferous coal basin. (Western portion). Ibid., 29, 192-7, 236-40, 282-7.

REID, J.H., 1928b - Mount Wyatt goldfield. Ibid., 29, 344-5.

REID, J.H., 1929a - Marginal formations of the Great Artesian Basin in Queensland. Rep. 5th Interstate Conf. artesian Water, Sydney, 1928, 30-2.

REID, J.H., 1929b - Geology of the Bowen River coalfield. Geol. Surv. Qld Publ. 276.

REID, J.H., 1929c - Coal prospects, Mackay district. Qld Govt Min. J., 30, 156-8.

REID, J.H., 1929d - Geological notes on the Mt Wyatt and Ukalunda mining fields. Ibid., 30, 158.

REID, J.H., 1930a - Geology of the Springsure district. Ibid., 31, 87-98, 149-55.

REID, J.H., 1930b - The Queensland Upper Palaeozoic succession. Geol. Surv. Qld Publ. 278.

REID, J.H., 1931 - The Cracow gold deposits. Qld Govt Min. J., 32, 473-6.

REID, J.H., 1932 - Correlations of the Queensland Permo-Carboniferous Basin. The Dilly Stage of the Lower Bowen Basin. Proc. Roy. Soc. Qld, 43, 56-65.

REID, J.H., 1935 - A summary of the copper resources of Queensland; in Copper Resources of the World. 16th int. geol. Cong., Washington, 751-7.

REID, J.H., 1936 - Blair Athol coalfield. Qld Govt Min. J., 37, 339-42.

REID, J.H., 1936 - Oil prospects at Springsure. Ibid., 37, 371.

REID, J.H., 1939 - Grasstree mine and goldfield, Sarina. Ibid., 40, 42-8.

REID, J.H., 1939 - Boring for oil, Saint Lawrence. Ibid., 40, 90.

REID, J.H., 1939 - Grasstree mine, Sarina. Ibid., 40, 220-1.

REID, J.H., 1939 - Marion and Junee, Mackenzie River. Ibid., 40, 221.

REID, J.H., 1939 - Dawson Valley Colliery, Baralaba, Mt Morgan Ltd. Ibid., 40, 257-8.

REID, J.H., 1940 - Report on the geology and hydrology of the Callide Valley, Queensland. Ibid., 41, 185-8.

REID, J.H., 1944 - Dawson coalfield, Baralaba. Ibid., 45, 204-5.

REID, J.H., 1945 - Callide coal. Ibid., 46, 47-9.

REID, J.H., 1945 - Dawson coalfield, Baralaba. Ibid., 46, 108-9.

REID, J.H., 1945 - The Dawson River area. Ibid., 46, 296-9.

REID, J.H., 1945 - Baralaba coalfield. Ibid., 46, 354-63.

REID, J.H., 1946 - Geological reconnaissance of the Nebo district coal areas. Ibid., 47, 10-13.

REID, J.H., 1947 - Report on the Callide coalfield. Ibid., 48, 12-17.

REID, J.H., and MORTON, C.C., 1928 - Central Queensland geological section. Ibid., 29, 384-9.

RICHARDS, H.C., 1918 - The building stones of Queensland. Proc. Roy. Soc. Qld, 30, 97-157.

RICHARDS, H.C., 1918 - The volcanic rocks of Springsure, central Queensland. Ibid., 30, 179-98.

RICHARDS, H.C., 1918 - The nature, occurrence, and origin of alunogen at Vandyke, near Springsure, central Queensland. Ibid., 30, 199-208.

RIDGWAY, J.E., 1940 - Bluff coalfield. Qld Govt Min. J., 41, 238-41.

RIDGWAY, J.E., 1943 - Chromite deposits, central district. Ibid., 44, 36-9.

ROBERTSON, C.S., 1961 - Emerald-Duaringa seismic survey. Bur. Miner. Resour. Aust. Rec. 1961/150 (unpubl.).

ROBERTSON, C.S., 1965 - Emerald-Duaringa seismic survey, Queensland, 1960. Ibid., 1965/2 (unpubl.).

RUNNEGAR, B.N., 1967a - Preliminary faunal zonation of the eastern Australian Permian. Qld Govt Min. J., 68(794), 552-6.

RUNNEGAR, B.N., 1967b - Desmodont bivalves from the Permian of eastern Australia. Bur. Miner. Resour. Aust. Bull. 96.

SAINT-SMITH, E.C., 1922 - Opal occurrences in the Springsure district. Qld Govt Min. J., 23, 188-9.

SANDERS, J.E., 1965 - Primary sedimentary structures formed by turbidity currents and related resedimentation processes; in Primary sedimentary structures and their hydrodynamic interpretation. Soc. econ. Paleont. Mineral. spec. Publ., 12, 192-217.

SHELDON, R.P., 1966 - Preliminary appraisal of the Australian continent for sedimentary phosphate deposits. Bur. Miner. Resour. Aust. Rec. 1966/16 (unpubl.).

SQD [Shell (Qld) Development Pty Ltd], 1952 - General report on investigations and operations carried out by the company in the search for oil in Queensland, 1940-1951. Geol. Surv. Qld, A-P Rep. 640 (unpubl.).

SHEPHARD, E.M., 1934 - Notes on the geological structure at Nathan Gorge, in the upper Dawson Valley, Queensland. Proc. Roy. Soc. Qld, 46, 83.

SHEPHERD, S.R.L., 1949 - Bowman coal mine - Styx River coalfield. Qld Govt Min. J., 50, 297-302.

SHEPHERD, S.R.L., 1951 - Test drilling of Nebo coalfield. Ibid., 52, 51-61.

SHEPHERD, S.R.L., 1951 - The Callide coalfield. Drilling in the upper Dunn's Creek section. Ibid., 52, 133-41.

SHEPHERD, S.R.L., 1951 - The Callide coalfield. Drilling in Peterson Gully section. Ibid., 52, 442-52.

SHIRLEY, J., 1898 - Additions to the fossil flora of Queensland, mainly from Ipswich Formation, Trias-Jura System. Geol. Surv. Qld Bull. 7. also Geol. Surv. Qld Publ. 128.

SHIRLEY, J., 1902 - Notes on fossil plants from Duaringa, Ipswich, Dawson River, and Stanwell. Geol. Surv. Qld Bull. 18.

SMITH, E.R., 1951 - Report on seismic refraction traverse at Comet, Queensland. Bur. Miner. Resour. Aust. Rec. 1951/9 (unpubl.).

SPECK, N.H., WRIGHT, R.L., SWEENEY, F.C., PERRY, R.A., FITZPATRICK, E.A., NIX, H.A., GUNN, R.H., and WILSON, I.B., 1968 - Lands of the Dawson-Fitzroy area, Queensland. Sci. ind. Res. Org., Land Res. Ser., 21.

STORY, R., GALLOWAY, R.W., GUNN, R.H., and FITZPATRICK, E.A., 1967 - Lands of the Isaacs-Comet area, Queensland. Sci. ind. Res. Org., Land Res. Ser., 19.

SWINDON, V.G., 1965 - Exploration methods in the Roma area. APEA, 1965 Conf. Paps, 133-8.

TEICHERT, C., 1950 - Climates of Australia during the Carboniferous, Permian and Triassic. 18th int. geol. Cong., Gt Brit., General Proc. Pt I, 206-8.

TEICHERT, C., 1951 - The marine Permian faunas of Western Australia. (An interim review). Palaont. Z., 24(1/2), 76-90.

TENISON WOODS, J.E., 1883 - On various deposits of fossil plants in Queensland. Proc. Linn. Soc. N.S.W., 7(1), 95-8.

THOMAS, G.A., 1958 - The Permian Orthotetacea of Western Australia. Bur. Miner. Resour. Aust. Bull. 39.

THOMSON, J.E., and DUFF, P.G., 1965 - Bentonite in the Upper Permian Black Alley Shale, Bowen Basin, Queensland. Bur. Miner. Resour. Aust. Rec. 1965/171 (unpubl.).

TISSOT, B., 1964 - Completion of a geological map of the Bowen Basin. Inst. franc. Petrole Rep. Aus/64.

TRAVES, D.M., 1962 - Recent developments in the Roma district. Aust. Oil Gas J., 8(4), 20.

TRAVES, D.M., 1966 - Petroleum in the Roma-Springsure area. 8th Cwealth Min. metall. Cong., Aust. N.Z., 5(136), 147-56.

UGC [United Geophysical Corporation], 1963 - Seismograph reflection survey, Clermont-Annandale area, ATP 55/56P, Queensland. Report to Mines Administration Pty Ltd.

UGC [United Geophysical Corporation], 1966 - Final report of sparker survey, Broad Sound area, Queensland. Unpublished report to Ampol Exploration (Qld) Pty Ltd.

VAN DER LINDEN, J., 1961 - Regional magnetic survey of Queensland and New South Wales, 1960. Bur. Miner. Resour. Aust. Rec. 1961/10 (unpubl.).

VEEVERS, J.J., MOLLAN, R.G., OLGERS, F., and KIRKEGAARD, A.G., 1964a - The geology of the Emerald 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rep. 68.

VEEVERS, J.J., RANDAL, M.A., MOLLAN, R.G., and PATEN, R.A., 1964b - The geology of the Clermont 1:250,000 Sheet area, Queensland. Ibid., 66.

VINE, R.R., 1966 - Recent geological mapping in the northern Eromanga Basin, Queensland. APEA, 1966 Conf. Paps, 110-15.

VINE, R.R., DAY, R.W., MILLIGAN, E.N., CASEY, D.J., GALLOWAY, M.C., and EXON, N.F., 1967 - Revision of the nomenclature of the Rolling Downs Group in the Eromanga and Surat Basins. Qld Govt Min. J., 68(746).

WALKOM, A.B., 1915 - Mesozoic floras of Queensland. Pt I: The flora of the Ipswich and Walloon Series. Geol. Surv. Qld Publ. 252, 8-51.

WALKOM, A.B., 1919 - Mesozoic floras of Queensland. Pts III and IV: The floras of the Burrum and Styx River Series. Ibid., 263, 7-78.

WALKOM, A.B., 1922 - Palaeozoic floras of Queensland. Pt I: The flora of the Lower and Upper Bowen Series. Ibid., 270.

WALKOM, A.B., 1932 - Notes on some recently discovered occurrences of the pseudomorph, glendonite. Proc. Linn. Soc. N.S.W., 38(1), 160-8.

WASS, R.E., 1965 - The marine Permian formations of the Cracow district, Queensland. J. Roy. Soc. N.S.W., 98(3), 159-68.

WASS, R.E., 1966 - Two new species of Permian brachiopods from Queensland. Proc. Linn. Soc. N.S.W., 91(1), 96-100.

WASS, R.E., 1967 - New species of Permian gastropods from Queensland. Ibid., 92(1), 67-73.

WATERHOUSE, J.B., 1958 - The occurrence of Atomodesma Beyrich in New Zealand. N.Z. J. Geol. Geophys., 1(1), 166-77.

WATERHOUSE, J.B., 1963a - The Permian faunal succession in New Zealand. J. geol. Soc. Aust., 19(1), 165-76.

WATERHOUSE, J.B., 1963b - Permian gastropods of New Zealand. 1- Bellerophontacea and Euomphalacea. 2- Pleurotomariacea (in part). 3- Pleurotomariacea (concluded) 4- Platyceratacea, Anomphalacea, Neritacea, and correlations. N.Z. J. Geol. Geophys., 6(1), 88-112; 6(2), 115-54; 6(4), 587-622; 6(5), 817-42.

WATERHOUSE, J.B., 1963c - Etheripecten, A new aviculopectinid genus from the Permian. Ibid., 6(2), 193-6.

WATERHOUSE, J.B., 1963d - New Zealand species of the Permian bivalve Atomodesma Beyrich. Palaeontology, 6(4), 699-717.

WATERHOUSE, J.B., 1964 - Permian brachiopods of New Zealand. N.Z. Geol. Surv. palaeont. Bull. 35.

WATERHOUSE, J.B., 1965a - Palaeotaxodont bivalves from the Permian of New Zealand. Palaeontology, 7(4), 630-55.

WATERHOUSE, J.B., 1965b - Generic diagnoses for some burrowing bivalves of the Australian Permian. Malacologia, 3(3), 367-80.

WATERHOUSE, J.B., and VELLA, P., 1965 - A Permian fauna from north-west Nelson, New Zealand. Roy. Soc. N.Z., Geol., 3(5), 57-84.

WEBB, E.A., 1956 - Review of exploratory oil wells penetrating Permian sections in central Queensland, Australia. Bull. Amer. Ass. Petrol. Geol., 40(10), 2329-53. (Reprinted in Aust. Oil Gas J., 3(7), 3-22, 1957).

WEBB, E.A., and CRAPP, C.E., 1960 - The geology of the Collinsville Coal Measures. Proc. Aust. Inst. Min. Metall., 193, 23-88.

WEBB, A.W., and McDOUGALL, I., 1967 - Isotopic dating evidence on the age of the Upper Permian and Middle Triassic. Earth planet. Sci. Lett., 2, 483-8.

WEBB, A.W., and McDOUGALL, I., 1968 - The geochronology of the igneous rocks of eastern Queensland. J. geol. Soc. Aust., 15(2), 313-46.

WELLS, R., and MILSOM, J.S., 1966 - Bowen Basin aeromagnetic and radiometric survey, Queensland, 1961-1963. Bur. Miner. Resour. Aust. Rec. 1966/208 (unpubl.).

WGC [Western Geophysical Co. of America], 1964 - Final report offshore area 93P and 94P, Queensland - Marine seismic. Unpublished report to Ampol Exploration (Qld) Pty Ltd.

WHITE, M.E., 1961 - Report on plant fossils from Bandanna Formation, Carnarvon Creek, Queensland. Bur. Miner. Resour. Aust. Rec. 1961/9 (unpubl.).

WHITE, M.E., 1961 - Report on 1960 plant fossil collections from the Bowen Basin, Queensland. Ibid., 1961/60 (unpubl.).

WHITE, M.E., 1962 - Report on 1961 plant fossil collections. Ibid., 1962/114 (unpubl.).

WHITE, M.E., 1963 - Report on 1962 plant fossil collections. Ibid., 1963/1 (unpubl.).

WHITE, M.E., 1963 - Report on east Bowen Basin plant fossil collections, 1962. Ibid., 1963/33 (unpubl.).

WHITE, M.E., 1964 - Report on 1963 collections of plant fossils from Taroom, Queensland. Ibid., 1964/37 (unpubl.).

WHITE, M.E., 1964 - Plant fossils from Baralaba, Queensland, 1963. Ibid., 1964/144 (unpubl.).

WHITEHOUSE, F.W., 1926 - The Cretaceous Ammonoidea of eastern Australia. Mem. Qld Mus., 8, 195-242.

WHITEHOUSE, F.W., 1930 - Report on a collection of fossils made by Mr J.H. Reid in the Springsure district. Qld Govt Min. J., 31, 156-7.

WHITEHOUSE, F.W., 1933 - On the presence of glendonites in the Dawson Valley. Proc. Roy. Soc. Qld, 44(11), 153-5.

WHITEHOUSE, F.W., 1940 - Studies in the late geological history of Queensland. Univ. Qld Dep. Geol. Pap., 2(1).

WHITEHOUSE, F.W., 1941 - Presidential address - The surface of western Queensland. Proc. Roy. Soc. Qld, 53, 1-22.

WHITEHOUSE, F.W., 1952 - The Mesozoic environments of Queensland. Aust. Ass. Adv. Sci. Rep., 29, 83-106.

WHITEHOUSE, F.W., 1955 - The geology of the Queensland portion of the Great Australian Artesian Basin. Appendix G in Artesian water supplies in Queensland. Dep. Co-ord. Gen. Public Works, parl. Pap. A.56, 1955.

WILCOX, W.T., 1926 - Fossil plants of Ipswich and Walloon age collected by Dr Jensen to the north of Roma; Appendix I in Geol. Surv. Qld Publ. 277.

WILKINSON, J.F.G., 1953 - Some aspects of the Alpine-type serpentinites of Queensland. Geol. Mag., 90(5), 305-21.

WOOLLEY, J.B., 1941 - Geological report on the area north-east of Tambo. Shell (Qld) Development Pty Ltd Rep., 5 (unpubl.).

WYATT, D.H., PAINE, A.G.L., CLARKE, D.E., GREGORY, C.M., and HARDING, R.R., 1971 - Geology of the Charters Towers 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rep. 137.

TABLE 1. DEVONIAN-CARBONIFEROUS ROCK UNITS OF THE CLERMONT BLOCK

Age		Rock Unit (map symbol)	Distribution and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
U. Devonian to L. Carboniferous	MOUNT RANKIN BEDS	Undifferentiated (D/Cr)	Discontinuous outcrops E of Anakie Inlier from E of Blair Athol to N of Mt Coolon (Malone et al., 1964, 1966; Veevers et al., 1964b)	Quartz-veined spherulitic flow-banded porphyritic rhyolite, dacite, pitchstone, andesite; acid and intermediate pyroclastics including agglomerate, volcanic conglomerate, and lapilli, crystal, and lithic tuff; tough fine to medium quartz-poor tuffaceous arenite, brown and grey siltstone. About 4800 m thick 65 km NE of Clermont.	Only slightly folded. Dips at 20°-50° in N and in type area; gentler dips W of type area possibly due to presence of shallow basement of Anakie Metamorphics. Unconformable on Anakie Metamorphics and Ukalunda Beds; unconformably overlain by Bulgonunna Volc	L. Carboniferous plants near top include Lepidodendron Lepidophyllum, Lepidostrobus all cf. L. aculeatum Stigmaria ficoides. Probably equivalent to and originally partly continuous with Drummond Basin sequence
U. Devonian	MOUNT RANKIN BEDS	Mount Wyatt Beds (Dum)	Type area and four smaller areas of outcrop about 50 km N of Mt Coolon (Malone et al., 1966)	Thin-bedded brown grey-green siltstone; fine to coarse and pebbly grey feldspatho-lithic sandstone, largely composed of volcanic detritus, quartzose sandstone; fossiliferous calcareous sandstone; beds and lenses of pebble to cobble conglomerate; green volcanic conglomerate; small-scale slump structures and clastic dykes common. About 300 m thick in type area	Dips at up to 55° away from underlying Ukalunda Beds. Appears to be local formation at base of Mt Rankin Beds, which unconformably overlie Ukalunda Beds	U. Devonian brachiopod Cyrtospirifer cf. reidi and Leptophloeum australe, Protolepidodendron, psilophytes, Stigmaria
U. Devonian to L. Carboniferous	DRUMMOND GROUP	Undifferentiated (Cld)	NW corner of map area (Malone et al., 1966)	Lithic sandstone, pebble to boulder conglomerate, and siltstone composed mainly of reworked volcanic detritus; minor quartz sandstone, grey chert, and thin beds and lenses of limestone. Acid to intermediate tuff, crystal tuff, agglomerate, and lava flows. Up to 3000 m thick	Moderately tight NE-trending folds; dips up to 80°, generally 30°-60°. Unconformable on Ukalunda Beds and Devonian-Carboniferous intrusions. Unconformably overlain by Bulgonunna Volc and intruded by U. Carboniferous intrusions	Carboniferous plants include Lepidodendron sp., Rhodia sp., Calamites sp.
L. Carboniferous	DRUMMOND GROUP	Ducabrook Formation (Clu)	Widespread in S part of Drummond Basin (Hill, 1952, 1957; Veevers et al., 1964a,b)	Typical sequence consists of coarse lithic sandstone with pink to pale green tuff, overlain by thin-bedded light green and brown fine sandstone, siltstone, mudstone, and shale, overlain by interbedded massive mottled sandstone and multi-coloured mudstone with thin beds of pink vitric tuff and dark oolitic and algal limestone. Proportion of each rock type varies from place to place. 2100-2700 m thick	Moderately elongate broad anticlines and synclines persisting for up to 80 km; dips rarely exceed 30°. Conformable or disconformable on Raymond Sst. Unconformably overlain by Joe Joe Fm	L. Carboniferous plants and fish include Lepidodendron cf. L. veltheimianum Sternberg, Gyracanthides murrayi, cf. Elonichthys

Table 1 (continued)

Age		Rock Unit (map symbol)	Distribution and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
L. Carboniferous		Raymond Sandstone* (Clr)	Along NE margin of S part of Drummond Basin W of Anakie and large anticline to W (Veevers et al., 1964a); in Nogoa and Telemon Anticlines and adjacent structures (Mollan et al., 1969; Hill, 1952, 1957)	Medium to fine light-coloured flaggy micaceous quartzose and sublabile sandstone. Near Anakie: interbedded mudstone, siltstone, medium to coarse feldspatholithic sandstone, arkose, thin basalt flows. Up to 660 m thick	Broad elongate anticlines; SW-dipping flank of Drummond Basin. Dips up to 40°	
		Mount Hall Conglomerate (Clh)	As for Raymond Sst	Cross-bedded quartz-pebble conglomerate and pebble quartzose sandstone, feldspathic and kaolinitic quartzose sandstone, mudstone. Lenticular unit up to 780 m thick	Raymond Sst conformable and transitional on Mt Hall Cgl where present; elsewhere disconformable on Telemon Fm. Mt Hall Cgl overlies Telemon Fm with disconformity or angular unconformity	Mt Hall Cgl contains Carboniferous plants including <u>Lepidodendron veltheimianum</u>. Whole Drummond Basin sequence probably deposited in fresh water
U. Devonian	DRUMMOND GROUP	Telemon Formation (Dut)	Along NE margin of S part of Drummond Basin (Veevers et al., 1964a,b); in Telemon and Nogoa Anticlines and adjacent structures (Mollan et al., 1969; Telemon Fm: Hill, 1957)	Basal part: cross-bedded massive conglomerate with lithofeldspathic tuffaceous matrix; pebbly sandstone. 600 m in Nogoa Anticline, lenses out to W. Top part: thinly interbedded multicoloured lutite and arenite, with cross-bedding, graded bedding, current striations, and sole markings; lenses of algal limestone. 1500 m in Nogoa Anticline, thins to W	Telemon Fm unconformably overlies and overlaps Silver Hill Volc, which rest unconformably on Anakie Metamorphics and Retreat Granite. Structures similar to those of overlying units, but both units cut by many faults in Nogoa and Telemon Anticlines	Basal conglomerate of Telemon Fm derived in part from Silver Hills Volc. Telemon Fm contains algae, fish scales, freshwater? branchiopod <u>Leaia</u>, and plants, including <u>Leptophloeum australe</u>, of U.? Devonian age
		Silver Hills Volcanics (Ds)	As for Telemon Fm (Veevers et al., 1964a)	Base: 240 m of weathered basalt and trachyte flows with lenses of resistant spherulitic rhyolite. Middle: 150 m of conglomerate, lithic arenite, siltstone, shale, trachyte flows. Top: 210 m of amygdaloidal porphyritic basalt, trachyte, andesite, agglomerate, crystal tuff, spilite, sandstone, and lithic greywacke		
M. and U. Devonian		Theresa Creek Volcanics (Dt)	Many isolated outcrops in small area of SW of Clermont (Veevers et al., 1964b)	Andesite, trachyandesite, flowbanded and spheroidal rhyolite, rhyolite breccia, dacite, basalt, crystal and lithic tuff; minor arkose, well bedded lithic arenite and siltstone, fine to medium cross-bedded calcareous feldspathic sandstone, and laminated red-brown micaceous siltstone. Thickness unknown	Structure obscured by massive nature of extrusions; thrust-faulted against Anakie Metamorphics. Relationships obscure: unconformable on Anakie Metamorphics, apparently conformable on M. Devonian sediments	No intrinsic evidence of age. Regarded as equivalent to Silver Hills Volc and basal volcanics of Mt Rankin Beds; may be older, equivalent? to Dunstable Volc

* Name amended to Raymond Formation (Olgers, in prep.)

TABLE 2. DEVONIAN-CARBONIFEROUS ROCK UNITS OF THE EUNGELLA-CRACOW MOBILE BELT

Age		Rock Unit (map symbol)	Distribution and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
U. Carboniferous	YARROL BASIN SEQUENCE	Neerkol Formation (Cu)	Long strips of E and W flanks of Craigilee Anticline; N part of Long Is (Malone et al., 1969; Kirkegaard et al., 1966; named in Reid, 1930b)	Mainly mudstone to sandy siltstone, blue-grey to black, tough, poorly bedded to massive, locally grading into fine sandstone; labile sandstone, fine to medium-grained, greenish grey, poorly bedded, scattered pebbles near base; minor crinoidal limestone, coquinite, and conglomerate beds near base. Estimated thickness 1500 m+ in Craigilee area	Broadly folded on Craigilee Anticline: E flank moderately and W flank steeply dipping; some minor cross-folding and faulting. Moderately folded and locally sheared on Long Is. Structurally conformable on L. Carboniferous, but faunas suggest disconformity; unconformably overlain by Youlambie Cgl and Rookwood Volc	Mudstone contains richly fossiliferous bands throughout, particularly bryozoans. Fauna includes Levipustula levis, Spinuliplica cf. Spinulosa, Composita cf. magnicarina, Alispirifer, Neospirifer, Reticulatia, Phricodothyris, Evactinopora, fenestellids, bryozoans, which indicate U. Carboniferous age
L. Carboniferous		(Cl)	Long strips on E and W flanks of Craigilee Anticline; N part of Long Is (Malone et al., 1969; Kirkegaard et al., 1966)	Basal part: siltstone and mudstone, grey to greenish grey, massive, cherty in part; some interbeds of fine to medium sandstone, commonly graded. Middle part: granule to pebble conglomerate, clasts mainly rounded volcanics, interbedded with oolitic limestone beds up to 6 m thick. Upper part: tough grey siltstone with thin to thick interbeds of fine to medium labile sandstone and coarse calcareous sandstone at top. Up to 600 m thick W of Craigilee Anticline, 2400 m E of anticline	Structure as for Neerkol Fm. Unconformable on Silurian-Devonian of Craigilee area; decrease in thickness of L. Carboniferous to W suggests that this unit onlapped subsiding Silurian-Devonian block from E	Some richly fossiliferous bands; limestones generally poorly fossiliferous. Fauna includes Productina, Pliocochonetes Schizophoria cf. resupinata, Rhipidomella, Lithostrotion spp., Syringopora, which indicate L. Carboniferous age
U. Devonian to U. Carboniferous		(D-Ca)	Small areas 30 km S of Marlborough and on Long Is (Malone et al., 1969; Kirkegaard et al., 1966)	S of Marlborough: green basic volcanics, mainly tuff, lapilli tuff, flows; volcanic conglomerate, greenish grey siltstone, interbeds of sandstone, oolitic limestone and green tuff Long Is: sandstone, blue-grey, coarse-grained, locally calcareous, thin pebble conglomerate interbeds; dark grey siltstone and mudstone, cherty in part; volcanics, limestone	Unconformably overlain by Rookwood Volc; faulted E margin; relationships to serpentinite and Youlambie Cgl obscure. Few dip measurements are steeply E Broad folds with some cross-folding and faulting	U. Devonian corals in lower volcanic part and L. Carboniferous fossils in limestone beds of middle-upper part Cyrtospirifer? sp. suggests U. Devonian age; rock types suggest sequence includes Carboniferous rocks

Table 2 (continued)

Age	Rock Unit (map symbol)	Distribution and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
U. Devonian to Carboniferous	Campwyn Beds (D-Cc)	Isolated blocks along coast from Repulse Bay to Carmila and inland at Koumala (Jensen et al., 1966; Jensen, 1963)	Dark green and purple andesite agglomerate and tuff, andesite, basalt, rhyolite, red and green rhyolite tuff, lapilli tuff, and volcanic breccia, minor trachytic volcanics, dark grey to black thin-bedded mudstone, well bedded or massive siltstone, calcareous siltstone, calcilutite, and labile sandstone, pebble conglomerate, oolitic limestone. Contact metamorphosed in places. Up to 7200 m thick	Broadly folded; dips rarely exceed 45°. W margins faulted against Permian rocks; nature of faulting unknown, but relative movement E block up. Equivalent in age and lithologically similar to Yarrol Basin sequence with which they may have been continuous	L. Carboniferous fauna, including Schuchertella sp. Rugosochonetes kennedyensis, Avonia kennedyensis, Athyris, Prospira tellebangensis, Camarotoechia, Aviculopecten, Chonetes, Bellerophon in places; elsewhere contains U. Devonian fuana: Alveolites sp., Thamnopora sp., Cyrtospirifer sp., Stenosia sp., Syringopora
Devonian to Carboniferous	Connors Volcanics (D/Co)	S end of Connors Arch and isolated inliers to E and S; isolated blocks on E and W margins of N part of Connors Arch (Malone et al., 1966, 1969)	Mainly massive rhyolite, dacite, trachyte, and andesite flows, tuff, agglomerate, breccia; extensively silicified, jointed, and quartz-veined. Some tuffaceous sediments and volcanic conglomerate, commonly jointed and quartz-veined. Intruded and contact metamorphosed in places	Structure obscure: rare bedding generally dips E; volcanics apparently consist of small folded wedge cut by many faults. Intruded by granodiorite of Carboniferous age and by younger intrusives. Unconformably overlain by L. Permian rocks. Onlapping of successively younger Permian units suggests parts of Connors Volc emerged at times during L. Permian	No known flora or fauna. Intruded by granodiorite with isotopic mineral ages of about 305 m.y. Tentatively correlated with Campwyn Beds because of similarity of lithology and structural position; S end may include equivalents of Silurian-Devonian volcanics

TABLE 3. UPPER CARBONIFEROUS TO PERMIAN ROCK UNITS

Age	Rock Unit (map symbol)	Distribution and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
U. Carboniferous to Permian	Joe Joe Formation (C-Pj)	Irregular area around SW margin of Drummond Basin (Hill, 1952, 1957; Mollan et al., 1969)	Lower part: Lithic conglomerate with subangular to rounded polymictic pebbles and boulders, some striated and facetted; unsorted conglomeratic light green sandy mudstone; lithic sandstone. Upper part: fine sandstone grading to siltstone, interlaminated siltstone and claystone (varves?), fine to medium lithic sandstone, carbonaceous shale, thin coaly beds, fine-grained grey limestone, vitric tuff; sediments: thin-bedded, laminated, cross-bedded on small scale, interference ripple marks. About 600 m thick	Only gently folded; gentle regional dip to S and Sw; some slight drape folding over pre-existing structures. Unconformable on Ducabrook Fm and overlaps older units; contact structurally conformable in places. Unconformably overlain by Reids Dome Beds and Colinlea Sst	Carboniferous plants, including Cardiopteria polymorpha, and spores. Spores suggest unit extends into Permian in subsurface to W. Basal part: mainly fluvioglacial; some beds of till; most of striated and facetted cobbles partly rounded. Upper part: mainly lacustrine
U. Carboniferous to Permian?	Torsdale Beds (Ct)	Elongate area 15 km NE of Banana and small area 50 km SE of Banana (Dear et al., in press)	Conglomerate, lithic sandstone, mudstone, chert, andesite, rhyolite, acid tuff, agglomerate	Faulted against Camboon Andesite, Auburn Complex, and Back Cr Gp; overlain by Back Cr Gp to E	May be partly fluvioglacial. Age and relationships not firmly established
U. Carboniferous	Bulgonunna Volcanics (Cub)	Large irregular area in NW part of map area (Malone et al., 1964, 1966)	Mainly porphyritic rhyolite with some trachyandesite; rhyolite weakly to strongly flow-banded, some with eutaxitic texture. Rhyolite and dacite crystal tuff, tuff, lapilli tuff, tuffaceous and volcanic conglomerate, rhyolite breccia and agglomerate; minor well bedded fine to coarse tuffaceous sandstone, siltstone, and conglomerate. Probably includes some intrusive rocks	Unfolded massive wedge of volcanics composed of overlapping, interfingering, or separate homogeneous lenses; gentle depositional dips around margins of lenses, steep in some lenses where bounded by faults, possibly marginal to foundering blocks. Unconformable on Drummond Gp, Mt Rankin Beds, and Ukalunda Beds; unconformably overlain by L. Permian volcanics and sediments	No fossils recorded. Intruded by plutons about 285 m.y. old. Probably U. Carboniferous; may be partly coeval with intrusive rocks

TABLE 4. EARLY LOWER PERMIAN ROCK UNITS

Rock Unit (map symbol)	Distribution and Main References	Lithology	Structure and Relationships	General Remarks
Reids Dome Beds (Plj) Oriou Formation (Plg)	Denison Trough and W part of basin (Mollan et al., 1969) Outcrops in core of Springsure Anticline (Mollan et al., 1969)	Sequence varies from place to place. Consists of alternating carbonaceous sandstone, grey siltstone and shale, and coal (Orion Fm) above thick dark shale with anhydrite, dolomite, coal, sandstone, and siltstone. Thick volcanolithic pebble conglomerate and volcanolithic sandstone near middle and base in places	Moderately folded in Denison Trough with dips up to 40°; gently dipping elsewhere. Sequence generally indurated, locally fractured and slickensided. Unconformable on Joe Joe Fm and pre-Permian basement in SW. Conformably, and transitionally?, overlain by Cattle Cr Fm in Denison Trough; unconformably overlapped by Colinlea Sst in W	Abundant Glossopteris/Gangamopteris flora. Rare marine fossils indicate occasional marine incursions. Orion Fm is only named unit of Reids Dome Beds which crops out
Lizzie Creek Volcanics (Plz)	N part of basin, mainly W of Connors Arch (as L. Bowen Volc: Malone et al., 1964, 1966; Malone et al., 1969; Jensen et al., 1966)	Andesite, dacite, rhyolite, trachyte, and basalt flows, tuff, agglomerate, breccia; sublabile, labile, volcanolithic, and tuffaceous sandstone, greywacke, siltstone, argillite, ashstone; pebble, cobble, and boulder conglomerate, volcanic conglomerate; fossiliferous limestone, calcareous lithic sandstone, calcareous tuff	Unconformable on Connors Volc and Bulgonunna Volc. Laterally equivalent to and locally continuous with Carmila Beds. Transitionally overlain and locally overlapped by Tiverton Subgp in most places; in Collinsville area, disconformably or unconformably overlain by Gebbie Subgp. Unconformably overlain by Calen Coal Measures in NE	Fossil wood and plants, including Glossopteris, Noeggerathiopsis, Cordaites, Samaropsis. L. Permian marine fossils of Fauna I near top
Carmila Beds (Pla)	N part of basin, mainly E and S of Connors Arch (Jensen et al., 1966; Malone et al., 1969)	Rhyolite, dacite; minor andesite flows and crystal tuff, volcanic conglomerate, lithic, feldspathic, and volcanolithic sandstone, tuff, ashstone, siltstone, mudstone; alternating tuffs and sediments. Fossiliferous calcareous tuff, limestone, and sandstone	Unconformable on Connors Volc. Unconformable on Campwyn Beds, but contacts generally faulted. Laterally equivalent to and locally continuous with Lizzie Cr Volc. Transitionally overlain and locally overlapped by Back Cr Gp. Unconformably overlain by Calen Coal Measures in NE	Noeggerathiopsis, Glossopteris, Gangamopteris, and near top L. Permian marine fossils of Fauna I and possibly Fauna II

TABLE 5. SEQUENCES PENETRATED IN PETROLEUM EXPLORATION WELLS

Well Name Ground Elevation (ft)	Rock Units	Post-Triassic	Moolayember Fm	Clematis Sst.	Rewan Fm.	Blackwater Gp	Blenheim Subgroup: Black Alley Sh.	Blenheim Subgroup: German Cr. Coal Measures	Peawaddy Fm	Gebbie Subgroup: Catherine Sst.	Gebbie Subgroup: Ingelara Fm	Aldebarah Sst.	Tiverton Subgroup: Cattle Cr Fm	Tiverton Subgroup: Buffel Fm & equivalents	Reids Dome Beds	Camboon Andesite	Pre-Permian	Total Depth (ft)
OSL3 (Arcadia) GE1392		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6036
AA07 (Arcadia GE1222		5* (10) +Cz			15 (330)	345 (705)	1050 (150)	- -	1200 (1050)	- -	- -	- -	- -	2250 (520)	2770 (510)	- -	- -	3280
AFO Arcturus No. 1 GE590		14 (126)T	-	-	140 (480)	620 (850	1470 (110)	1580 (550)	2130 (990)	3120 (200)	3320 (90)	3410 (2090)	5500 (703)	-	-	-	-	6203
AAO Bandanna No. 1 GE1420		-	-	-	-	-	-	-	10 (290)	-	300 (180)	480 (950)	1430 (680)	-	2110 (1933)	-	-	4043
UKA Burunga No. 1 GE1074		18 (2013)	-	-	2031 (50)	2081 (2575)	-	4656 .x. (4924)	-	-	-	-	-	9580 (221)	-	9801 (180)	9981 (261)	10242
UKA Cockatoo Creek No. 1 GE656		18 (707) J-K	-	-	725 (2590)	3315 (2280)	-	5595 (5725)	-	-	-	-	-	11320 (598)	-	11918 (164)	-	12082
AFO Comet No. 1 GE600		-	-	-	-	-	-	-	15 (675)	690 (30)	720 (155)	875 (1055)	1930 (425)	-	-	-	2355 (655)	3010
AP Cometside No. 1 GE824		-	-	-	12 (838	850 (890)	1740 (340)	-	2080 (1150)	-	-	3230 (430)	3660 (1455)	-	5115 (446)	-	-	5561
AOE3 (Consuelo) GE988		-	-	-	-	-	-	-	-	-	-	12 (2168)	2180 (2257)	-	-	-	-	4437
AFO Cooroorah No. 1 GE595		-	-	-	-	-	-	10 (380)	390 (820)	1210 θ (428)		1638 (1002)	2640 (370)	-	-	-	3010 (513)	3523
Planet Crystalbrook No. 1 GE1647		11 949 J-K	960 (580)	1540 (320)	1860 (140)	-		-	-	-	-	-	-	-	-	-	2000 (61)	2061
Amoseas Cunno No. 1 GE1796		12 (1193) J-K	1205 (880)	2085 (355)	-	2440 (185)	-	2625 .x. (156)	-	-	-	-	-	-	-	-	2781 (47)	2828
Marathon Glenhaughton No. 1 GE1814		15 (260)	275 (1740)	2015 (1000)	3015 (3670)	6685 (735)	-	7420 .x. (1525)	-	-	-	-	-	8945 (370)	-	-	9315 (103)	9418
AAO Glentulloch No. 1 GE1507		11 (1564) J-K	-	-	1575 (110)	1685 (135)	-	-	1820 (840)	-	-	-	-	-	2660 (1345)	-	4005 (83)	4088

* Depth from RT or KB to formation top elevation KB or RT equals ground elevation plus distance to top of formation at surface. + Formation thickness. .x. Undifferentiated Blenheim Subgroup θ Undifferentiated Catherine Sst and Ingelara Fm.

TABLE 5 (continued)

Well Name Ground Elevation (ft)	Rock Units	Post-Triassic	Moolayember Fm	Clematis Sst	Rewan Fm	Blackwater Gp	Blenheim Subgroup Black Alley Sh.	Blenheim Subgroup German Cr. Coal Measures	Blenheim Subgroup Peawaddy Fm	Gebbie Subgroup Catherine Sst.	Gebbie Subgroup Ingelara Fm	Aldebarah Sst.	Tiverton Subgroup Cattle Cr Fm	Tiverton Subgroup Buffel Fm & equivalents	Reids Dome Beds	Camboon Andesite	Pre-Permian	Total Depth (ft)
OSL2 (Hutton Creek) GE1510		7 (333) J-K	-	-	-	-	-	340 ·x. (550)	-	-	-	-	-	-	890 (3798)	-	-	4688
AFO Inderi No.1. GE710		10 (90)Cz				100 (90)	190 (100)	290 (640)	930 (740)	1670 (20)	1690 (180)	1870 (2140)	4010 (1360)	-	5370 (63)	-	-	5433
AAO Kildare No. 1 GE1590		14 (1610) J-K	-	-	1624 (786)	2410 (320)	2730 (260)	-	2990 (770)	-	-	-	-	-	3760 (1964)	-	-	5724
AAO Kildare No. 2 GE1613		14 (1612) J-K	-	-	1626 (179)	1805 (355)	2160 (289)	-	2449 (696)	-	-	-	-	-	3145 (4522)	-	-	7667
AAO Killoran No 1 GE1697		10 (1890) J-K						1900·x. (405)	-	-	-	-	-	-	-	-	2305 (44)	2349
S QD Morella No. 1 RT965		-	-	-	0 (900)	900 (510)	1410 (470)	-	1880 (820)	-	-	2700 (1165)	3865 (495)	-	4360 (274)	-	-	4634
A P Eotley No. 1 GE769		-	-	-	13 (887)	900 (820)	1730 (340)	-	2070 (1150)	-	-	3220 (440)	3660 (527)	-	-	-	-	4187
A AO Purbrock No. 1 GE783		-	-	-	10 (660)	670 (820)	1490 (345)	-	1835 (1200)	-	-	3035 (365)	3400 (1350)	-	-	-	4750 (199)	4949
A P Purbrook South No. 1. GE817		-	-	-	13 (2187)	2200 (820)	3020 (290)	-	3310 (1150)	-	-	4460 (406)	4866 (716)	-	-	-	-	5582
A OE Reids Dome No. 1 G E 969		-	-	-	-	-	-	-	-	-	-	-	10 (1685)	-	1695 (7365)	-	-	9060
A FO Rolleston No. 1 GE683		9 (66)Cz	-	-	75 (625)	700 (685)	1385 (465)	-	1850 (1090)	2940 (80)	3020 (105)	3125 (1475)	4600 (2530)	-	7130 (2378)	-	-	9508
A FO Struan No. 1 GE650		-	-	-	15 (615)	630 (870)	1500 (120)	1620 (510)	2130 (930)	3060 (110)	3170 (170)	3340 (1660)	5000 (920)	-	5920 (114)	-	-	6034
AFO Sunlight No. 1 GE835		-	-	-	15 (1280)	1295 (985)	2280 (260)	2540 (330)	2870 (1060)	3930 (12)	3942 (43)	3985 (468)	4453 (409)	4862 (91)	-	-	4953 (47)	5000
Planet Tooloombilla No. 1 G E1358		9 (1511) J-K	1520 (208)	-	-	-	-	-	-	-	-	-	-				1748 (2) Granite	1750
Planet Warrinilla No. 1 GE1005		16 (74)Cz	-	-	90 (1440)	1530 (440)	1970 (505)	-	2475 (805)	-	-	3280 (395)	3675 (1035)	-	4710 (1991)	-	-	6701

TABLE 5 (continued)

Well Name / Ground Elevation (ft) — Rock Units	Post-Triassic	Moolayember Fm	Clematis Sst	Rewan Fm	Blackwater Gp	Blenheim Subgroup		Peawaddy Fm	Gebbie Subgroup		Aldebarah Sst.	Tiverton Subgroup		Reids Dome Beds	Camboon Andesite	Pre-Permian	Total Depth (ft)
						Black Alley Sh	German Cr Coal Measures		Catherine SSt.	Ingelara Fm		Cattle Cr Fm	Buffel Fm & equivalents				
Planet Warrinilla N. No. 1 GE1020	16 (39)Cz	-	-	55 (1005)	2060 (410)	2470 (475)	-	2945 (780)	3725 (125)	3850 (160)	4010 (1635)	5645 (1000)	-	6645 (234)	-	-	6879
Planet Warrong No. 1 GE2043	9 (506) J-K	515 (990)	1505 (315)	1820 (240)	2060 (75)	-	2135** (650)	-	-	-	-	-	-	-	-	2785 (789)	3574
AAO Westgrove No. 1 GE1702	13 (697)	-	-	710 (940)	1650 (350)	2000 (270)	-	2270 (810)	-	-	3080 (530)	3610 (520)	-	4130 (2312)	-	-	6442
AAO Westgrove No. 3 GE1719	13 (749)	-	-	762 (631)	1393 (327)	1720 (230)	-	1950 (670)	-	-	2620 (730)	3350 (226)	-	3576 (9057)	-	-	12663
AFO Yandina No. 1 GE660	15 (205)T	-	-	-	220 (190)	410 (190)	600 (790)	1390 (680)	2070 (30)	2100 (190)	2290 (268)	-	-	-	-	-	2558

TABLE 6. ROCK UNITS OF THE TIVERTON SUBGROUP

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Sirius Formation (Pls)	Stanleigh Fm, Staircase Sst, and Sirius Fm crop out in parallel elongate belts around the N-trending Springsure Anticline, from 40 km N to 48 km SSE of Springsure in Springsure and Emerald Sheet areas. Formations difficult to distinguish W of Emerald where they are mapped as Tiverton Subgp	Staircase Cr just S of Springsure-Rolleston road (Webb, 1956; Mollan et al., 1969)	Interbedded grey-blue mudstone, grey to buff siltstone containing flakes and encrustations of gypsum and jarosite, and soft brown poorly bedded argillaceous lithic sandstone. 105 m thick in type area; thins to N and S	Three formations form conformable sequence; Sirius/Staircase contact sharp, Staircase/Stanleigh contact gradational. Sequence grades to E and S into Cattle Cr Fm with reduction in proportion of sandstone. Stanleigh Fm transitionally overlies Orion Fm at top of Reids Dome Beds. Sequence folded into elongate N-trending Springsure Anticline	L. Permian marine fossils (Fauna II)
Staircase Sandstone (Plt)	As for Sirius Fm above	Type section along Springsure-Rolleston road near Staircase Cr (Reid, 1930a; Mollan et al., 1969)	Mainly cross-bedded quartzose sandstone containing some lithic grains and feldspar in type area; to S, sandstone better sorted and more mature; to N and S contains interbeds of siltstone and mudstone. 210 m thick in type area; thins to 126 m in N	As for Sirius Fm above	Cross-bedding azimuths suggest W source. Rare marine fossils; some casts of logs and plants
Stanleigh Formation (Plh)	As for Sirius Fm above	Near Stanleigh homestead; type section in Orion Cr 8 km N of homestead, Springsure Sheet area (Phillips, in Hill & Denmead, 1960; Mollan et al., 1969)	Upper unit: dark grey to dark blue, poorly bedded, locally micaceous, carbonaceous mudstone and siltstone with gypsum and jarosite along bedding planes and joints; some beds contain ferruginous accretions containing pebbles and fossil shells. Middle unit (Riverstone Sst Mbr: Power, 1966): cross-bedded pebbly lithic sublabile sandstone with minor tuff, feldspar, and biotite, interbedded with mudstone and siltstone as above. Lower unit: mudstone and siltstone, as for upper unit; thin sandstone interbeds and bed of conquinitic limestone ('Eurydesma limestone') near base in N. Total thickness 438 m in type area	As for Sirius Fm above	Locally abundant L. Permian marine fossils (Fauna II). Rare Glossopteris
Cattle Creek Formation (Plk)	Exposed in core of Reids Dome, Springsure Sheet area; recognized subsurface throughout Denison Trough	Cattle Cr, 53 km SW of Rolleston, and section in AOE 1 (Reids Dome) from surface to 1695 ft (516.6 m) (Hill, 1957; SQD, 1952; Mollan et al., 1969)	Upper part in type area consists of dark grey poorly sorted poorly bedded conglomeratic silty sandstone and mudstone containing scattered large angular boulders, with thin interbeds of limestone and calcareous sandstone; sandstone argillaceous, lithic, sublabile, contains mica, carbonaceous material, and lenses and bands of gypsum and jarosite along bedding planes. Complete sequence in AOE 1 is dominantly dark grey mudstone, with interbeds of sandstone, calcareous siltstone, and silty limestone. 1685 ft (513.6 m) thick in AOE 1 (Reids Dome)	Generally gently dipping; crops out only along crest of Reids Dome. Transitionally overlies Reids Dome Beds in Denison Trough. To SE and E, basal part replaced by dominantly calcareous unit (Buffel Fm), which unconformably overlies eroded Reids Dome Beds or pre-Permian rocks	Abundant L. Permian marine fossils (Fauna II). Near Top contains 3-m bed of limestone, called 'Eurydesma limestone' by Reid (1930a), but not equivalent to 'Eurydesma limestone' at base of Stanleigh Fm

TABLE 6. (continued)

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Buffel Formation (Plu)	Exposed in isolated lenses from Cracow to near Banana and S of Biloela; tentatively identified in wells to W	Buffel Hill 8 km S of Cracow (Wass, 1965; Mollan et al., in press)	Fossiliferous limestone grading laterally and vertically into hard white aphaniticchert or silicified limestone, in places overlain by blue-green hard mudstone with lenses of dark blue-grey calcilutite; volcanolithic pebble conglomerate with grey fossiliferous limestone matrix at base in places; limestone: purple, brown, or white, coarse, and commonly thick-bedded. Max of 60 m exposed, but top eroded	Unconformable or disconformable on Camboon Andesite; disconformably overlain by Oxtrack Fm. Mainly dips gently W between Cracow and Banana; preserved in trough of tight syncline near Cracow; more tightly folded S of Banana. Probable equivalents of Buffel Fm included in undifferentiated Back Cr Gp between Nebo and Fitzroy R	Abundant L. Permian marine fossils (Fauna II)
Tiverton Subgroup (undifferentiated) (Plp)	N part of basin from near Nebo to near Collinsville	Narrow strip extending for 20 km NNW from Hazelwood Cr (Malone et al., 1966, 1969)	Upper unit (Cattle Cr Fm equivalent?): grey-blue siltstone and mudstone, roughly laminated with irregular dark mudstone partings, generally hard and closely jointed, some gypsum and rare jarosite; hard calcareous siltstone nodules or accretions up to 2.5 m across, either scattered or in layers; fossiliferous calcareous siltstone near base. 390 m thick. Lower unit (Buffel Fm equivalent?): grey medium to fine feldspathic and lithic labile and sublabile sandstone with carbonaceous streaks and laminae in places, interbedded with dark grey-blue laminated to medium-bedded siltstone and mudstone, fossiliferous calcareous siltstone and sandstone, limestone and coquinite; hard volcanolithic sandstone at base. Max thickness 330 m	Conformable or locally disconformable on Lizzie Cr Volc. Conformably overlain and overlapped to N by Gebbie Subgp. Dips moderately to steeply SW off Connors Arch; locally indurated, jointed, and sheared. Upper unit very poorly exposed, and apparently locally faulted out in part at N end of type area	Abundant L. Permian marine fossils (Fauna II), mainly in lower unit.

TABLE 7. ROCK UNITS OF THE GEBBIE SUBGROUP

(Southern part of Bowen Basin)

Rock Unit (map symbol)	Distribution	Type area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Colinlea Sandstone (Plo)	W part of basin. (Fluvial environment. Fig. 11a.)	Along Central Western Highway in Colinlea Holding (Hill, 1957; SQD,1952; Mollan et al., 1969).	Fine to medium planar and festoon cross-bedded kaolinitic quartz sandstone with thin soft purple siltstone interbeds and granule-pebble-cobble conglomerate mainly near base; clasts in conglomerates include milky quartz, fine sandstone, quartzite, chert, and acid volcanics. Sandstone thick to medium-bedded near base, thin-bedded to laminate near top	Dips gently to S and E off Drummond Basin. Lateral equivalent of middle and top parts of Aldebaran Sst and of Catherine Sst; Ingelara Fm not represented. Unconformable on Reids Dome Beds and pre-Permian units; conformably overlain by Peawaddy Fm	Plant fossils including *Vertebraria*; ferruginized logs in basal conglomerate. Palynological data support correlation with Aldebaran and Catherine Ssts. Mainly fluviatile sedimentation
Aldebaran Sandstone (Pl1)	Denison Trough: recognized in SW part of basin as far N as Coorooah	S branch of Aldebaran Cr 40 km SSE of Springsure (Reid, 1930a; Mollan et al.,1969)	Upper member (Freitag Fm,Power, 1966): quartzose sandstone, rarely conglomeratic and micaceous, thinly interbedded with fissile siltstone; worm tubes and oscillation ripple marks common. 45-75 m thick. Middle member: conglomeratic quartzose sandstone with beds of conglomerate containing pebbles as for Colinlea Sst conglomerate; truncated planar cross-bedding, festoon cross-bedding, and scour channels common. 90-240 m thick. Lower member: fine to medium feldspathic quartzose sandstone containing pebbles of fine sandstone,siltstone, and milky quartz, interbedded with carbonaceous mudstone and rare thin coal seams. 90-330 m thick	Dips at up to 40° on flanks of Springsure and Consuelo Anticlines and Reids Dome; gently dipping elsewhere. Lower member transitional on Tiverton Subgp; separated by local erosional unconformity from middle member. Upper member conformable on middle member in outcrop; Power (1966) suggests Upper member overlies major erosional unconformity in subsurface to E and S; Ingelara Fm transitionally succeeds upper member	L. Permian marine fossils (Fauna III) in upper member. Mainly deposited in deltaic, rarely fluvial environment; member boundaries mark major regression and transgression. Irregular lateral thickness variations suggest several distributaries supplied sediment to delta
Ingelara Formation (Pli)	Denison Trough; subsurface distribution as for Aldebaran Sst	5 km NNW of Ingelara homestead (Raggatt & Fletcher, 1937; Hill, 1957; Mollan et al., 1969)	Poorly sorted and poorly bedded conglomeratic sandy siltstone and mudstone, carbonaceous, pyritic, lenses and bands of gypsum and jarosite, large calcareous fossiliferous concretions. Large angular boulders, similar to those in Cattle Cr Fm, around S nose of Reids Dome. 36 m thick in type area; max of 160 m 65 km N	Dips at up to 35° on flanks of Springsure and Consuelo Anticlines and Reids Dome. Transitionally overlies Aldebaran Sst; conformably, in places transitionally, overlain by Catherine Sst; S of S nose of Reids Dome disconformably overlain by Peawaddy Fm	L. Permian marine fossils of Fauna III, possibly of same age as fauna in middle unit of Gebbie Subgp in N part of basin. Deposited in rapidly subsiding marine basin with little sorting
Catherine Sandstone (Plf)	Denison Trough as far S as S nose of Reids Dome; in subsurface: E to Rolleston 1 and N to Comet 1	Mt Catherine area (Reid, 1930; Mollan et al., 1969)	Cross-bedded fine to medium well sorted quartzose to sublabile sandstone, containing up to 15% potash feldspar in places, interbedded with thin poorly exposed mudstone intervals. 90 m thick in type area; max 135 m	Lateral equivalent to upper part of Colinlea Sst. Disconformably overlain and overlapped by Peawaddy Fm; wedges out because of non-deposition or erosion beneath Peawaddy Fm to S and E	L. Permian marine fossils (Fauna III). Deposited in paralic and shallow marine environments during last stage of subsidence of Denison Trough

TABLE 8. ROCK UNITS OF THE GEBBIE SUBGROUP

(Northern part of Bowen Basin)

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Gebbie Subgroup (Plb)	Long strip along W flank of Connors Arch and in large anticline in Folded Zone, 55 km N of Bluff	Gebbie Cr 22 km SSE of Collinsville (Malone et al., 1966, 1969)	Upper unit: fine to medium sublabile sandstone, interbedded with grey-blue siltstone, dark carbonaceous mudstone, and rare ripple-marked quartzose sandstone; scattered pebbles, conglomerate beds, and calcareous fossiliferous layers in places. 120 m thick; thins to 69 m S of type area. Middle unit: interbedded grey-blue siltstone and quartzose to sublabile sandstone in type area; mainly blue-grey coarse siltstone grading to semifriable silty sandstone to S. 120-150 m thick. Lower unit: quartzose to sublabile sandstone, micaceous, feldspathic, carbonaceous in part, with interbeds of grey-blue siltstone; at base 30 m of grey-blue coarse micaceous, locally carbonaceous, siltstone with worm tubes and calcareous fossiliferous beds, grading up into silty sandstone and quartzose sandstone. 150 m thick in type area; thickens to 225 m to S	Moderate to steep SW dips along flank of Connors Arch. Moderately tight asymmetric large-amplitude folds in Folded Zone. Sequence exposed in Folded Zone consists of adjacent parts of lower and middle units. Three units have transitional contacts. Gebbie Subgp disconformably overlies, and to N overlaps, Tiverton Subgp. Disconformably overlain in type area and possibly conformably overlain S of type area by Blenheim Subgp. Gebbie Subgp, above middle of lower unit, dominantly marine lateral equivalent of Collinsville Coal Measures	L. Permian marine fossils of Fauna III abundant in basal 30 m and sporadically distributed throughout rest of Gebbie Subgp. Lower unit includes Wall Sst Mbr (Reid, 1924-25). Middle unit contains same fauna as Glendoo Sst Mbr (Webb & Crapp, 1960) of Collinsville Coal Measures. Deposited in paralic environment; Wall Sst Mbr may have been deposited as sand bar
Collinsville Coal Measures (Plc)	Broad belt extending 65 km W and S from Collinsville	Collinsville area (Reid, 1924; Webb & Crapp, 1960; Malone et al., 1966)	Mainly grey very fine to medium micaceous sandstone, conglomeratic in places, interbedded with dark grey siltstone, mudstone, carbonaceous shale, and coal seams; poorly sorted polymictic pebble-cobble conglomerate at base; Glendoo Sst Mbr, marine sandstone as above, fossilerous and calcareous in places, with thin siltstone member or coal measures; sequence includes 11 named coal seams including 2 about 6 m thick. 225 m thick in type area	Dips gently to S and E; faulted E margin near Collinsville; cut by minor faults to W. Disconformably overlies and overlaps Lizzie Cr Volc. Overlapped SW of Collinsville by Blenheim Subgp. Glendoo Sst Mbr correlates with part of middle unit of Gebbie Subgp in type area	L. Permian marine fossils (Fauna III) in Glendoo Sst Mbr and abundant *Glossopteris* flora above and below. Deposited in swampy, brackish, or freshwater lagoon, with occasional marine transgression

TABLE 9. POSSIBLE EQUIVALENTS OF THE GEBBIE SUBGROUP

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Blair Athol Coal Measures (Pa)	5 small areas centred about 10 km NNW of Clermont	Blair Athol area (Reid, 1936; Veevers et al., 1964b)	Fine sandstone, dark blue-grey carbonaceous mudstone and shale, coal, fine conglomerate; quartz-pebble conglomerate, locally auriferous, at base in places. Main coal seem 33 m thick. Max thickness 240 m	Depositional dip locally modified by compaction of coal; some minor faulting. Unconformable on irregular basement of Anakie Metamorphics. Coal seams interfinger with sediments near margins of basin	Abundant *Glossopteris* flora; some possibly L. Permian spores. Deposited in isolated small basin, near margin of basin
Calen Coal Measures (Ple)	Elongate belt extending 55 km NW from Pioneer R to about 25 km W of Mackay	Calen area (Hill *in* Hill & Denmead, 1960, p. 222; Reid, 1929c; Jensen et al., 1966)	Cross-bedded thick-bedded brown to white coarse well sorted quartzose sandstone, with quartz and quartzite pebble bands; thinly interbedded sandstone, as above, and siltstone grading into soft brown mudstone; thin coal seams. 300 m thick	Folded into elongate basin; dips around margin up to 20°. Some local minor folds. Intruded by many sills and dykes and cut by numerous, mainly NW-trending, faults. Unconformable on Carmila Beds and Lizzie Cr Volc	*Glossopteris* and *Vertebraria*. Possibly deposited in small partly marine, basin on margin of marine depositional area of Gebbie Subgp

TABLE 10. ROCK UNITS OF THE BLENHEIM SUBGROUP

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Undifferentiated Blenheim Subgroup (Pue)	On W flank of Connors Arch and at N end of Collinsville Shelf. Forms most of sequence exposed around Bundarra Granodiorite	Blenheim Cr 67 km SE of Collinsville (Malone et al., 1966, 1969; Jensen, 1968).	Upper unit; fine to coarse quartzose sandstone, silty, micaceous, calcareous, cross-laminated, abundant worm tubes in places; minor dark micaceous mudstone. 35 m thick. Middle unit: dark blue to dark grey micaceous mudstone, grading into shale in places; some calcareous fossiliferous mudstone and coquinite horizons, rare scattered pebbles. 270 m thick. Lower unit: coarse grey-blue micaceous carbonaceous mudstone and siltstone interbedded with and grading into fine to coarse silty sublabile sandstone. Sequence calcareous and fossiliferous in places; contains scattered pebbles and angular boulders. Abundant worm tracks in some beds: some beds of conglomeratic coquinitic mudstone and sandstone. About 420 m thick	Dips moderately to steeply SW off Connors Arch; steeply dipping to overturned locally near Blenheim Cr; SW dip interrupted by minor folding in places. Low S dips and minor folds on N end of Collinsville Shelf. Three units form conformable sequence which conformably succeeds Gebbie Subgp. Overlaps Gebbie Subgp to W and unconformably overlies Bulgonunna Volc and U.Carboniferous intrusions.	Abundant early U. Permian marine fossils of Fauna IV. Most fossils found in discrete coquinitic beds, which are usually conglomeratic; bryozoans, crinoid ossicles, and worm tracks much more widespread. Deposited in shallow to moderately deep sea. Sandstone more abundant in W. Lower unit includes Big *Strophalosia* Zone (Reid, 1925).
Undifferentiated Blenheim Subgroup (Pue)	Capella Block and outliers to W	(Veevers et al., 1964b)	Top unit: medium to coarse cross-bedded quartzose to sublabile sandstone, argillaceous in places, alternating with siltstone, locally micaceous and carbonaceous: contains plants, wood, and thin coal seams. (Passage Beds: Reid, 1924-25). Up to 600 m thick; thins to S. Lower unit: silty sandstone, siltstone, rare coal, basal conglomerate with boulders of granite and schist, conglomeratic coquinitic *Strophalosia clarkei* bed and pelecypod beds. About 45-60 m thick	Dips gently E. Unconformable on Mt Rankin Beds and Anakie Metamorphics farther S. Overlaps Gebbie Subgp in most places; conformably overlain by Blackwater Gp. 'Passage Beds' lens out to S or are replaced by part of German Cr Coal Measures which overlie lower unit	Abundant marine fossils of Fauna IV in some beds. Top unit contains freshwater sediments with plants, rootlets, and wood. Deposited in partly marine and partly freshwater environment near margin of depositional area. Lower unit deposited in advancing sea
German Creek Coal Measures (Pud)	N part of Comet Ridge; in subsurface, tentatively recognized as far S as Rolleston	German Cr 7 km NE of Emerald (Malone et al., 1969)	Quartz sandstone and sublabile sandstone, cross-bedded, rarely ripple-marked, worm-tracked, micaceous and carbonaceous on cross-laminae; micaceous, carbonaceous siltstone and mudstone; coal; quartz-pebble conglomerate; interbedded sandstone, sandy siltstone, and siltstone. Max thickness 240 m	Gently folded on Comet Ridge and to S; regional E dip on S margin of Capella Block. Conformable on Maria Fm on Comet Ridge and on undifferentiated basal part of Blenheim Subgp to N. Basal part appears to be lateral equivalent of upper sandy part (including Mantuan *Productus* bed) of Peawaddy Fm	Marine fossils of Fauna IV and plant remains in some beds. Possibly deposited in mainly marine deltaic environment

Table 10 (continued)

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Maria Formation (Pum)	Exposed on N part of Comet Ridge	Maria Cr about 48 km ESE of Emerald (Derrington et al., 1959; Malone et al., 1969)	Sandstone and silty sandstone, fine to medium-grained, argillaceous, calcareous, micaceous and carbonaceous; grey and dark grey siltstone and silty mudstone, micaceous, calcareous, locally pyritic; minor thin coal seams. Up to 240 m thick	Gently folded on Comet Ridge. Lateral equivalent of Peawaddy Fm below Mantuan Productus bed. Possibly disconformable on Gebbie Subgp	Some marine fossil detritus but no diagnostic faunas known. Deposited in marine environment
Black Alley Shale (Puc)	Exposed on flanks of Springsure and Consuelo Anticlines and in W part of basin	W branch of Dry Cr, 3 km SE of Black Alley Peak, 64 km SSW of Rolleston (Mollan et al., 1969)	Dark shale and claystone, with 0.3–0.6-m beds of soft green soapy bentonite and several beds of tuff and tuffaceous claystone with glass shards; thin hard ferruginous beds, minor siltstone, and rare sandstone. 90–150 m thick; may be thicker in subsurface to SE	Moderately tightly folded in Denison Trough; gently dipping to S in W part of basin. Structurally conformable on Peawaddy Fm; partly lateral equivalent of and partly younger than German Cr Coal Measures	No diagnostic marine fossils. Presence of swarms of acritarchs suggests marine environment. Bentonite produced from volcanic ash by diagenesis in restricted depositional environment, either freshwater or marine
Peawaddy Formation (Pup)	Exposed on flanks of Springsure and Consuelo Anticlines, and in W part of basin	Peawaddy Cr 64 km SSE of Springsure (Mollan et al., 1966, 1969)	Grey siltstone and dark carbonaceous mudstone, thinly interbedded and interlaminated, micaceous, abundant plant debris, locally worm burrows, and gypsum and jarosite ? on bedding planes; lithic sandstone, dominant in upper half of unit; very fossiliferous coquinitic siltstone and sandstone of Mantuan Productus bed at top in places	Structure as for Black Alley Sh. Basal unit of Blenheim Subgp in SW of basin. Conformable or disconformable on Gebbie Subgp in Denison Trough, but disconformably overlaps older units to SW	Abundant U.Permian marine fossils of Fauna IV, particularly at top. Probably deposited in marine environment throughout
Banana Formation (Pum)	Exposed on W flank of Auburn Arch from 16 km S of Cracow to near Banana, and on E edge of arch S of Biloela	Banana area (Derrington et al., 1959; Dear et al., in press)	Grey, dark grey, and olive green mudstone and siltstone; thin beds of feldspatholithic labile sandstone. Local thickness up to 600 m: lenses out to S	Dips W at 10°–30° off W flank of Auburn Arch. Near Banana: involved in faulting and folding which becomes tighter towards E; S of Biloela: very tight folds within fault slices; in north: some shearing and cleavage in sediments. Local mudstone development at top of Blenheim Subgp	Upper Permian sediments deposited in environment transitional from marine to freshwater
Flat Top Formation (Puf)		Flat Top Mountain, Banana district (Derrington et al., 1959; Dear et al., in press; Mollan et al., in press	Hard buff to blue mudstone grading laterally into buff argillite, interbedded with light grey calcareous lithofeldspathic silty sandstone, locally fine to coarse sandstone, both containing volcanic detritus, and thin beds of hard limestone and coquinite. 540 m thick; thins to 225 m in N	Top formation of Blenheim Subgp in most of Auburn Arch area	Upper Permian marine fossils of Fauna IV in a few beds mainly

TABLE 10 (continued)

Rock Unit (map symbol)	Distribution	Type rea and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Barfield Formation (Pur)		Barfield homestead, Banana area (Derrington et al., 1959; Dear et al.,in press; Mollan et al.,in press)	Dominantly massive green to dark blue mudstone with interbedded grey and black calcareous concretions and glendonites; some blue-grey calcilutite and grey laminated mudstone, green and brown lithic sandstone and pebbly sandstone; lapilli tuff, agglomerate, andesite, and lithic arenite; includes thick lithic sandstone and interbedded sandstone/siltstone sequences in N. 900 m thick; much thicker between Banana and Biloela	As for Banana and Flat Top Fms above. Dominant formation of Blenheim Subgp in Auburn Arch area, particularly in N. May be largely lateral equivalent of Boomer Fm	Abundant Upper Permian marine fossils of Fauna IV. Fossils and abundant glendonites suggest deposition in cold marine environment
Oxtrack Formation (Puo)		Oxtrack Cr 24 km NNW of Cracow (Derrington et al.,1959: Mollan et al.,in press; Dear et al., in press)	Fossiliferous brown flaggy limestone grading laterally into calcareous siltstone, silicified limestone, fossiliferous calcareous mudstone grading to coquinite; hard white lithic sandstone interbedded with siltstone; 30-105 m thick.	As for Banana and Flat Top Fms above. Basal formation of Blenheim Subgp; disconformably overlies Buffel Fm and Camboon Andesite	Abundant early Upper Permian marine fossils of Fauna IV. Deposited in shallow sea
Boomer Formation (Puu)	Discontinuous large outcrops throughout Gogango Overfolded Zone and N to Connors Arch and Strathmuir Synclinorium	Boomer Ra. Type section in Leura Cr 40 km SW of Marlborough (Malone et al., 1969)	Thin to medium interbeds of very fine to medium volcanolithic labile sandstone, dark blue siltstone and dark carbonaceous claystone; sandstone dominates sequence in places, usually in thick beds, but absent in other places; in places siltstone contains wisps and balls of dark sandy claystone; locally abundant conglomerate. Max measured thickness 375 m;true thickness possibly 1500 m or more	Very tightly to moderately folded, faulted and cleaved; gentler dipping off SW flank of Connors Arch. Lateral equivalent of Barfield Fm and possibly Flat Top Fm. To E, lateral equivalents are very thick and conglomeratic Moah Cr and Dinner Cr Beds. (Kirkegaard et al., 1966,and in prep.)	Very poorly fossiliferous some marine fossils of Fauna IV; laterally equivalent units all marine and contain Fauna IV fossils. Boomer Fm probably deposited in early Upper Permian sea; only formation of Blenheim Subgp in this area

TABLE 11. PERMIAN ROCK UNITS OF THE EUNGELLA-CRACOW MOBILE BELT

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Rookwood Volcanics (Pr)	Separate blocks of outcrop in Gogango Overfolded Zone and near Goovigen	Along Melaleuca Cr near Rookwood homestead about 25 km NE of Duaringa (Malone et al., 1969)	Spilitic pillow lavas; minor agglomerate, volcanic breccia, silicified trachyte, keratophyre; chert, silicified sandstone and mudstone. Est thickness 900 m+	Thick lenses of volcanics generally unfolded; dips to SW off flank of Craigilee Anticline. Interfingers with and overlain by Boomer Fm and Moah Cr Beds; unconformable on Youlambie Cgl and U. Carboniferous; rests unconformably on Rannes Beds in places, but elsewhere relationship uncertain	No fossils. U. Permian age based on stratigraphic relationships. Submarine basaltic extrusion possibly related to intrusion of ultrabasic differentiate in Marlborough area
Youlambie Conglomerate (Ply)	Small areas on SW margin of Craigilee Anticline. Main development E of map area	Youlambie Cr in Monto Sheet area (Dear et al., in press; Malone et al., 1969; Kirkegaard et al., 1966, and in prep.)	Lithic and volcanolithic pebble conglomerate, thinly to thickly interbedded with feldspatholithic labile sandstone and siltstone, laminated cherty siltstone interbedded with sandstone; mudstone; silicified sandstone and siltstone; blue massive or laminated chert; andesite sills and flows. Thickness unknown, very thick to E	Dips SW off Craigilee Anticline and off block of Devonian to Carboniferous (D-Ca) at N end of anticline. Unconformably overlain by Rookwood Volc; in N, faulted? against Rannes Beds but relationship unknown. Unconformable on U. Carboniferous	_Noeggerathiopis hislopi_ of L. Permian age; just E of area contains small marine microfauna of early L. Permian age. Local conglomeratic sedimentation in Yarrol Basin associated with local uplifts
Unnamed Lower Permian (Pl)	Quail Is and on mainland to S	(Kirkegaard et al., in prep.)	Siltstone with ferruginous concretions, feldspathic sandstone, lithic conglomerate. 4500? m thick	Overlies Neerkol Fm; faulted? against L. Palaeozoic? metamorphics. Possible equivalent of Youlambie Cgl	L. Permian marine fauna

TABLE 12. ROCK UNITS OF THE BLACKWATER GROUP

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Blackwater Group (Puw)		Blackwater area (Malone et al., 1969; Jensen, 1968)	Blackwater area: consists of Rangal Coal Measures, Burngrove Fm, and Fair Hill Fm (see below). 435 m thick. Baralaba-Cracow area: consists of Baralaba Coal Measures and Gyranda Fm (see below). Up to 825 m thick. Elsewhere mapped as undifferentiated (see below)	Structure varies from area to area. Conformable or disconformable on Back Cr Gp; unconformably, disconformably, and conformably overlain by Rewan Fm in different places	Abundant Glossopteris flora of Permian to L. Triassic age, usually in particular beds. Permian on stratigraphic position, but may extend into L. Triassic.
Undifferentiated (Puw)	N part of basin	(Malone et al., 1964, 1966; Veevers et al., 1964b; Jensen et al., 1966; Jensen, 1968)	Fine to coarse, usually well sorted, grey-green to brown calcareous lithic sandstone; grey and blue siltstone, dark carbonaceous mudstone; brown calcareous sublabile sandstone, sandy calcarenite; tuffaceous lithic sandstone, hematitic in places, tuffaceous siltstone; conglomerate; coal seams, especially near top but minor seams throughout; hard, white cherty tuff and chert? Up to 2100 m thick	Moderately tightly folded in Nebo Synclinorium, but dip rarely more than 40°; gentler folding and regional E dips on Collinsville Shelf. Apparently conformable on Back Ck Gp and conformably overlain by Rewan Fm	No marine fossils. Deposited in fluvial, lacustrine, or paludal environments. Dominance of volcanic detritus contrasts with predominance of quartz in underlying Blenheim Subgp in N. Prominent fossil log horizons in places, usually associated with tuff or tuffaceous sediments. Contains probable late U. Permian spores, markedly different from spore assemblage in overlying Rewan Fm
Undifferentiated (Puw)	Folded Zone	(Malone et al., 1969)	Lithic sandstone, siltstone, mudstone, coal, calcareous and tuffaceous sediments as above; also interbedded and intergrading lithic sandstone and siltstone. About 1200 m thick	Very tightly folded and steeply dipping; folding becomes less intense to W and N. Similar to sequence on Comet Ridge but much thicker. Top and bottom relationships as in N part of basin	As for Puw in N part of basin
Undifferentiated (Puw)	Denison Trough and W part of basin	(Mollan et al., 1969)	Thinly interbedded green, commonly calcareous, lithic sandstone, siltstone, dark carbonaceous mudstone, coal, oil shale, claystone, ferruginous siltstone. 60-90 m thick	Moderately folded in Denison Trough; dips gently to S in W part of basin. Structurally conformable on Black Alley Sh but possibly disconformable	As for Puw in N part of basin
Rangal Coal Measures (Puj)	E flank of Comet Ridge	Deep Cr 10 km SW of Blackwater (Malone et al., 1969)	Mudstone, carbonaceous mudstone, feldspathic and volcanolithic sandstone, calcareous sandstone, carbonaceous shale, coal seams. 210 m thick	Dips regionally to E off Comet Ridge at low angles; some minor cross-folds and local folds, and minor faulting. Topmost unit of Blackwater Gp; conformably or disconformably overlain by Rewan Fm	U. Permian to L. Triassic? Probably deposited in paludal environment, less commonly lacustrine or fluvial. Fossil logs in one horizon

TABLE 12 (continued)

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Burngrove Formation (Pug)	From 24 km S to 64 km W of Blackwater	Burngrove Cr W of Blackwater (Malone et al., 1969)	Green, yellow, grey, and white cherty mudstone, dark grey, blue, and brown hard siltstone, siliceous and possibly tuffaceous in part; interbedded to interlaminated siltstone and buff fine sandstone; dark grey to black shale, grey labile and calcareous sandstone. 90 m thick	Structure as for Rangal Coal Measures. Conformable between the Rangal Coal Measures above and Fair Hill Fm below	Abundant well preserved plants in thin cherty mudstone beds. Probably deposited in shallow lakes
Fair Hill Formation (Pul)	As for above two units; also NW of Comet Ridge	E flank of Comet Ridge N of Blackwater (Malone et al., 1969)	Trough cross-stratified lithic and feldspathic labile sandstone, in places quartz-rich and approaching sublabile sandstone; siltstone, mudstone, interlaminated mudstone and fine sandstone; calcareous sandstone grading into sandy limestone; tuffaceous sandstone, volcanolithic pebble conglomerate, rare thin beds of green chert and white sandstone; minor carbonaceous mudstone; coal. 115-135 m thick	As above, and gently folded on NW flank of Comet Ridge. Basal formation of Blackwater Gp. Conformably overlies German Cr Coal Measures	U. Permian; abundant fossil logs in places. Probably deposited in fluvial environment; rarely paludal or lacustrine
Baralaba Coal Measures (Pul)	Baralaba to Cracow area	Baralaba (Reid, 1944, 1945; Olgers et al., 1966; Dear et al., in press; Mollan et al., 1969)	Carbonaceous mudstone and shale; medium to coarse trough cross-stratified feldspatholithic sandstone; minor lithic sublabile sandstone; coal; bands of calcareous sandstone nodules and concretionary ironstone. 210-360 m thick	Dips west at 10°-25° along flank of Auburn Arch with some minor folding and faulting. Tightly folded near Baralaba with dips up to 80° and many faults. Top formation of Blackwater Gp in Baralaba to Cracow area; probably equivalent to Rangal Coal Measures	Abundant *Glossopteris* flora. Probably deposited in part of widespread late Permian paludal environment
Gyranda Formation (Puy)	Baralaba to Cracow area	Back Cr near Cracow (Derrington et al., 1959; Mollan et al., 1969; Dear et al., in press; Jensen, 1968)	Green trough cross-stratified lithic sandstone, partly tuffaceous; calcareous sandstone; hard thinly laminated green to brown mudstone; volcanolithic pebble conglomerate; upper part consists of hard white and brown fine cherty tuff and minor volcanic breccia. 480 m thick	As for Baralaba Coal Measures above. Conformable on Flat Top Fm. Upper tuffaceous member may be equivalent to Burngrove Fm	Abundant *Glossopteris* flora, particularly in upper member; tuffs from upper member give isotopic age of 240 m.y. (Webb & McDougall, 1967)

TABLE 13. DISTRIBUTION CHART OF PERMIAN SPECIES

	Fauna I	Fauna I? (Stanleigh Formation)	Fauna II	Fauna II (Sirius Shale)	Fauna IIIA	Fauna IIIB	Fauna IIIC	Fauna III (Ingelara and Catherine Formations)	Fauna III (Ingelara equivalent - Folded Zone)	Fauna IV (Oxtrack Formation)	Fauna IV
Pachymyonia cf. etheridgei	X										
Notospirifer sp. A	X										
Megadesmus cf. antiquatus	X	X									
Eurydesma hobartense	X	X	X								
Astartila cf. gryphoides	X	X	X		X	X	?		X[1]		
Warthia sp.	X	X	X		X	X	X	X			X
Aviculopecten sp.	X	X	X								X
Deltopecten limaeformis	X		X								
Chaenomya sp. nov. A	X		X								
Myonia cf. davidis	X		X								
Ingelarella profunda	X		X								
Notospirifer hillae plicata	X		X								
Merismopteria sp.	X		X			X					X
Pseudomyalina sp.		X									
Oriocrassatella queenslandica		X									
Megadesmus cf. noblissimus		X	X								
Stutchburia cf. randsi		X	X								
Cypricardinia? cf. gregaria		X	X								
Modiolus sp.		X	X								
Notospirifer extensus		cf	X	cf	X						
Chaenomya sp.		X	X								X
Notospirifer hillae			X								
Pseudosyrinx sp. nov.			X								
Spiriferellina sp.			X								
Keeneia sp.			X								
Terrakea pollex			X								
Taeniothaerus subquadratus			X								
Ingelarella denmeadi			X								
Streptorhynchus sp. nov.			X								
Ptychomphalina sp.			X								
Terrakea or Cancrinella sp.			X								
Strophalosia preovalis var. warwicki			X								
Strophalosia cf. preovalis or jukesi			X								
Strophalosia jukesi			X								
Strophalosia brittoni			X								
Taeniothaerus subquadratus var acanthophorus			X								
Trigonotreta or Pseudosyrinx sp.			X								
Aviculopecten cf. leniusculus			X								
Aviculopecten cf. comptus			X								
Aviculopecten cf. fittoni			X								
Aviculopecten sp. nov.			X								
Deltopecten squamuliferus			X								
Deltopecten sp.			X								
Astartella sp. nov.			X								
Mourlonia (Mourlonia) sp. nov.			X								
Bembexia sp. nov. A			X								
Taeniothaerus sp.			X								
Schizodus sp. nov. A			X								
Pseudomyalina cf. mingenewensis			X								
Streplopteria cf. englehardti			X								

TABLE 13 (continued)

	Fauna I	Fauna I? (Stanleigh Formation)	Fauna II	Fauna II (Sirius Shale)	Fauna IIIA	Fauna IIIB	Fauna IIIC	Fauna III (Ingelara and Catherine Formations)	Fauna III (Ingelara equivalent - Folded Zone)	Fauna IV (Oxtrack Formation)	Fauna IV
Parallelodon sp. nov. A			X								
Trigonotreta sp. A			X								
Gilledia sp. nov.			X								
Streblochondria? sp.			X								
Ingelarella ovata			X	X							
Ingelarella plana			X	X							
Ingelarella plica			X	X							
Cancrinella farleyensis			X	X							
Anidanthus springsurensis			X	X							
Strophalosia preovalis			X	X							
Neospirifer (Grantonia) cf. hobartensis			X	X							
Terrakea sp.			X	X	X			X			X
Glyptoleda reidi			cf		X			X			X
Cancrinella sp.			X	X	X						X
Neospirifer sp. A			X	X				X		X	X
Schizodus sp.			X		X						
Glyptoleda buarabae			cf		X			X			
Neospirifer sp.			X			X					X
Streblopteria sp.			X				X	X		X	X
Peruvispira sp.			X					X		X	
Lissochonetes sp.			X					X	X^2		X
Atomodesma sp.			X								X
Plekonella sp.			X								X
Cancellospirifer sp.			X								X
Aviculopecten tenuicollis			X								X
Palaeosolen? sp.			X								X
Trigonotreta sp.				X							
Atomodesma cf. mytiloides					X						
Megadesmus sp. nov.					X						
Wilkingia? sp. nov.					X						
Pseudomonotis sp. nov.					X						
Ingelarella sp.					X						
Chaenomya sp. nov. B					X			X	X^1		
Stutchburia costata					cf	cf	cf	X			X
Mourlonia (Platyteichum) costatum					X		X	X			
Ingelarella ingelarensis					cf		cf	X	X^2		X
Pachymyonia sp. nov.					X			cf			
Parallelodon or Cypricardinia						X					
Volsellina? sp.						X					
Pelecypoda gen. et sp. nov.						X					
Bembexia sp. nov. B						X			X^2		
Cypricardinia? sp.						X	X				
Aviculopecten cf. subquinquelineatus						X	X				
Schizodus sp. nov. B						X	?				
Notospirifer sp. C						cf	cf	X			
Notospirifer sp. B						?	X				X
Megadesmus sp.						?	X				X
Mourlonia (Walnichollsia)? sp.						X		X			X
Notomya or Pyramus sp.						X					X
Phestia sp.						X					X

TABLE 13 (continued)

	Fauna I	Fauna I? (Stanleigh Formation)	Fauna II	Fauna II (Sirius Shale)	Fauna IIIA	Fauna IIIB	Fauna IIIC	Fauna III (Ingelara and Catherine Formations)	Fauna III (Ingelara equivalent - Folded Zone)	Fauna IV (Oxtrack Formation)	Fauna IV
Notomya? sp. nov.							X				
Astartidae gen. et sp. nov. A							X				
Ingelarella undulosa							X				
Mourlonia (Mourlonopsis) cf. strzeleckiana							X				X
Peruvispira sp. nov.							X				X
Stutchburia cuneata							X				X
Stutchburia cf. compressa							X				X
Atomodesma exaratum								X			
Elimata sp. nov.								X			
Spiriferellina? sp.								X			
Pseudosyrinx? sp.								X			
Plekonella acuta								X	X^2		
Parallelodon sp. nov.								X	X^2		
Conocardium sp.								X	X^2	X	X
Plagiostoma? sp.								X		X	X
Cancrinella magniplica								X	X^2	cf	cf
Volsellina? mytiliformis									cf	X	X
Ingelarella mantuanensis								X		X	X
Pyramus? sp.								X			X
Strophalosia sp.								X	X^2		X
Strophalosia cf. typica								X			X
Ingelarella angulata								X	X^1		X
Anthraconeilo sp.								X			X
Glyptoleda glomerata								X			X
Atomodesma (Aphanaia) sp.									X^2	X	X
Parallelodon sp. nov. B										X	X
Attenuatella sp.									X^2		X
Nuculopsis (Nuculopsis) sp.									X^1		X
Neospirifer sp. B										X	X
Terrakea solida										X	X
Strophalosia clarkei										X	X
Strophalosia clarkei var. minima										X	X
Strophalosia ovalis										X	X
Cleiothyridina sp.											X
Thamnopora sp.											X
Cladochonus sp.											X
Calceolispongia sp. nov.											X
Ingelarella cf. isbelli											X
Ingelarella magna											X
Ingelarella cf. magna or mantuanensis											X
Ingelarella havilensis											X
Ingelarella sp.											X
Chaenomya? cf. carinata											X
Myonia carinata											X
Myonia cf. corrugata											X
Licharewia sp. nov.											X
Mourlonia (Platyteichum) coniforme											X
Mourlonia (Walnichollsia) subcancellata											X
Atomodesma bisulcatum											X
Nuculopsis (Nuculanella) sp.											X

TABLE 13 (continued)

	Fauna I	Fauna I? (Stanleigh Formation)	Fauna II	Fauna II (Sirius Shale)	Fauna IIIA	Fauna IIIB	Fauna IIIC	Fauna III (Ingelara and Catherine Formations)	Fauna III (Ingelara equivalent - Folded Zone)	Fauna IV (Ortrack Formation)	Fauna IV
Quadratonucula sp.											X
Pyramus sp.											X
Pseudomonotis? sp.											X
Cyrtorostra? sp.											X
Schizodus sp. nov. C											X
Stachella sp.											X
"Martinia" sp.											X
Notospirifer minutus											X
Streptorhynchus pelicanensis											X
Productidae, gen. et sp. nov.											X
Astartila cf. cytherea											X
Astartila sp.											X
Astartidae gen. et. sp. nov. B											X
Aviculopecten sp. A											X
Megadesmus grandis											X
Strophalosia cf. brittoni var. gattoni											X
"Solemya" edelfeti											X
Trigonotreta sp. B											X

1 Basal sandstone

2 Siltstone overlying sandstone

Compiled from species distribution charts in B.M.R. Reports 100, 123, and 142 modified from later collections and other work by H.M. Doyle.

TABLE 14. ROCK UNITS OF THE MIMOSA GROUP

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Moolayember Formation (TRm)	On Redcliffe Tableland; between Carborough Ra and Kerlong Ra; in Mimosa Syncline and to W; strip extending across W part of basin	Along Injune-Rolleston road near Moolayember Cr (Reeves, 1947; Olgers et al., 1966; Mollan et al., 1969, and in press; as Teviot Fm, a synonym of Moolayember Fm: Malone et al., 1964)	Green to brown mudstone and labile, rarely sublabile, sandstone. Beds commonly calcareous, and contain green-brown altered biotite? Sandstone consists mainly of fragments of volcanic rock and minor feldspar; finer-grained to W. Thick beds of volcanolithic pebble to cobble conglomerate near base in E; some beds of quartzose sandstone in transition zone from Clematis Sst. Minor carbonaceous shale and fine cherty tuff? Mainly calcareous micaceous lithic sandstone and siltstone in N. Max thickness of 1650 m in Mimosa Syncline; much thinner to N and W	Low S dips in W; dips up to 25° off flanks of Springsure Anticline; generally preserved in synclines, elsewhere dips about 10° or less. Transitional into overlying Clematis Sst, but may be disconformable in places near margin of basin. Unconformably overlain by Precipice Sst	Plants, including species of Dicroidium, Thinnfeldia?, Sphenopteris, Phyllopteris. Spore assemblage indicates M. to U. Triassic age. Deposited in rapidly subsiding fluvio-lacustrine, probably reducing, environment; presence of acritarchs suggests occasional periods of brackish water
Clematis Sandstone (TRe)	Redcliffe Tableland, Carborough Ra, Kerlong Ra, and Burton Ra; thin ridge to broad range around Mimosa Syncline; S part of Denison Trough and across W part of basin	Gorge of Clematis Cr in Expedition Ra (Jensen, 1926a; Whitehouse, 1955; Olgers et al., 1966; Mollan et al., 1969, and in press; as Carborough Sst, a synonym of Clematis Sst: Malone et al., 1964, 1966; Malone et al., 1969)	Fine to very coarse and pebbly thick-bedded cross-stratified lithic and feldspathic sublabile sandstone and quartzose sandstone, with interbeds of reddish brown micaceous mudstone and grey-white siltstone. Volcanolithic labile sandstone and conglomerate common in SE. Sandstone generally contains large proportion of argillaceous or micaceous matrix. Max thickness of 300 m in Mimosa Syncline, thinner to W; possibly 450 m in Carborough Ra area	Preserved in synclines in N with limbs dipping at up to 15°; dips at up to 15° in Mimosa Syncline and synclines to W and up to 25° off Springsure Anticline; low S dip in W part of basin. Middle unit of Mimosa Gp. Transitional on Rewan Fm in N and in E limb of Mimosa Syncline, but disconformable on or locally overlaps Rewan Fm to S and W	Plants include species of Dicroidium, Cladophlebis, Sphenopteris, and Neocalamites. Spore assemblage suggest L. to M. Triassic age. Deposited in slowly subsiding fluvial environment, possibly mainly in river channels rather than flood-plains
Rewan Formation (TRr)	Poorly exposed between Clematis Sst and Blackwater Gp throughout most of basin. Also crops out in Folded Zone and on E flank of Comet Ridge	Small tributary of Consuelo Cr 6 km N of Rewan homestead (Mollan et al., 1969, and in press; Olgers et al., 1966; as part of U. Bowen Coal Measures: Malone et al., 1964, 1966; Malone et al., 1969)	Red-brown and green massive mudstone, red ferruginous claystone; green to brown fine to very coarse and pebbly labile and volcanolithic sandstone, commonly calcareous; volcanolithic pebble conglomerate; sublabile sandstone near top in places. Grainsize and proportion of volcanic detritus decreases from E to W and from bottom to top. Coarser-grained or sandy basal unit generally overlain by dominantly mudstone unit. Max. thickness of 3600 m in Mimosa Syncline, much thinner to W; up to 1050 m in N part of basin	Structure generally similar to that of overlying Clematis Sst. Tightly folded in Folded Zone; dips gently E off Comet Ridge. Basal unit of Mimosa Gp. Disconformable, or in places unconformable, on Blackwater Gp; possibly transitional on Blackwater Gp in N part of basin. May include slight angular unconformity near base in SW	Poorly preserved fossil plants in few places. Contains mainly L. Triassic spore assemblage though deposition may have commenced near end of U. Permian. Deposited in rapidly subsiding shallow lacustrine and partly fluvial oxidizing? environment

TABLE 14 (continued)

Rock Unit (map symbol)	Distribution	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Sagittarius Sandstone Member (TRs)	E flank of Comet Ridge for 32 km S and N of Blackwater	Sagittarius Cr $1\frac{1}{2}$ km N of Blackwater (Malone et al., 1969)	Green or grey-green fine to medium, rarely coarse and pebbly, festoon-bedded feldspathic and lithic labile sandstone; grey, greenish grey, or light green fine silty sandstone, siltstone, and mudstone; rare carbonaceous mudstone and plant-bearing dark siltstone; thin pebble conglomerate bands; red-brown mudstone interbeds more common near top; shale-pebble conglomerate and thin cone-in-cone limestone lenses near base in places. Up to 450 m thick	Dips regionally to E at low angles, but folded into many low-amplitude ripple folds. Basal member of Rewan Fm in Blackwater area. Member readily distinguished from upper part of formation in which red-brown mudstone predominates. May be equivalent to lower part of Rewan Fm in type area. Locally disconformable on Blackwater Gp, but in places may be transitional	No marine faunas or diagnostic floras known. Conchostrichons in thin limestone bands. Spore assemblages suggest mainly L. Triassic age, but may be partly U. Permian. Deposited in rapidly subsiding fluvial environment
Brumby Sandstone Member (TRb)	Arcadia Cr area; present but not delineated on flanks of S Springsure Anticline	Brumby Mt, near Arcadia Cr, 65 km NNW of Injune (Mollan et al., 1969, and in press)	Poorly sorted dense tough lustre-mottled very coarse pebbly sandstone with fragments of volcanic rocks and grains of green chert. Generally forms ridges. 4.5-9 m thick	Dips at up to 25° off flanks of Springsure Anticline and at lower angles off Arcadia Anticline. Member near base of Rewan Fm. Locally unconformable on Blackwater Gp or on thin basal sequence of Rewan Fm	Fluvial sedimentation. L. Triassic age based on spore assemblages in adjacent rocks

TABLE 15. ROCK UNITS OF THE GREAT ARTESIAN BASIN SEQUENCE

Rock Unit (map symbol)	Distribution and Topography	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Roma Formation (Klr)	SW corner of map area; subdued, mainly covered by Cainozoic sediments	Along Wallumbilla Cr for 19 km S of Wallumbilla township (Day, 1964; Vine et al., 1967)	Grey laminated siltstone and mudstone, weathering yellow-brown; hard thin-bedded nodular calcareous fine sandstone and mudstone, ferruginized in outcrop; gritty, locally glauconitic, sublabile sandstone near base. 60 m thick; thicker to S	Conformable and possibly transitional on Hooray Sst. Unconformably overlain by lateritized Tertiary sediments in map area	No fossils known in map area; elsewhere contains marine Aptian macrofauna. Deposited during widespread marine transgression; thin-bedding and fine grain-size suggest mainly low-energy depositional environment
Blythesdale Formation (Klb)	S margin of map area, about 40 km SW of Injune; forms low sand-covered scarps	Along Blyth Cr in Roma Sheet area (Day, 1964)	White to brown fine to medium porous quartzose sandstone with quartz pebbles and bands of claystone clasts; small-scale cross-bedding, rare ripple marks, numerous worm casts; minor siltstone and mudstone beds containing plant debris in places. 9-24 m thick	Local member (Claravale Sst Mbr, Mollan et al., in press) of Blythesdale Fm. Possibly disconformable on Orallo Fm. At top of sequence in map area	Unstudied macroflora and microflora. Correlated with units regarded as L. Cretaceous on palynological data. Fluviolacustrine or possibly paralic
Orallo Formation (Juo) (=Southlands Formation; Mollan et al., in press)	S margin of map area, about 40 km SW of Injune; generally low relief	Type section of Southlands Fm: 38 km WSW of Injune	Upper part: thinly bedded mudstone, siltstone, and very fine quartzose to sublabile sandstone, locally calcareous; rare beds of gritty coarse sandstone. Locally, 15-cm ironstone band at top Lower part: thick-bedded, cross-bedded, medium and rarely fine-grained, calcareous argillaceous labile to sublabile sandstone, with pebble bands. 120-150 m thick	Conformably overlies Gubberamunda Sst. Laterally equivalent to Orallo Fm plus lower members of Blythesdale Fm in Roma area, and to part of Hooray Sst to W	Unstudied macroflora and microflora. Correlated with units containing U. Jurassic to L. Cretaceous spore assemblages (Evans, 1966b). Fluvial and later lacustrine
Gubberamunda Sandstone (Jug)	SW of Injune near S margin of map area; forms low rises and cuestas	Roma-Injune road from 32-38 km N of Roma (Reeves, 1947; Day, 1964)	Medium to thick-bedded cross-bedded fine to coarse pebbly argillaceous porous quartzose to lithic sublabile sandstone, with abundant plant impressions and clay clasts in some beds; quartz-pebble conglomerate with sandstone matrix as above; minor grey-green thin-bedded to laminated siltstone and claystone. 60-75 m thick	Conformable, probably transitional, on Westbourne Fm. Laterally equivalent to lower part of Hooray Sst to W	U. Jurassic spore assemblage. Large-scale cross-bedding and coarse grain-size suggest fluvial environment; possibly derived from S or SE
Hooray Sandstone (J-Kh)	N-trending belt in SW part of map area; forms dissected plateaux with steep scarps and rare cuestas	Hooray Cr 19 km ENE of Tambo (Exon, 1966)	White medium to thick-bedded cross-bedded coarse argillaceous sublabile sandstone containing scattered pebbles, glauconite, and some worm tubes; thick-bedded cross-bedded pebble conglomerate with sandy matrix as above; some beds of feldspathic sublabile and quartzose sandstone, white mudstone, and claystone. 120 m thick	Conformable on Westbourne Fm, but locally basal sands have scoured tops of siltstone units in Westbourne Fm. Contains unconformity of unknown magnitude	No flora or fauna known. Correlated with U. Jurassic to L. Cretaceous units. Possibly fluvial

TABLE 15 (continued)

Rock Unit (map symbol)	Distribution and Topography	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Westbourne Formation (Juw)	SW corner of map area and W of Injune along S edge of map area; low relief with rare cuestas	From 1279-1651 ft (389.8-503.2 m) in Westbourne 1 (Gerrard, 1964; Exon, 1966)	Grey thin-bedded to laminated carbonaceous, micaceous, and in places calcareous, siltstone and mudstone with ferruginous (after calcite?) discoidal concretions in places; thin to thick-bedded fine to very fine sublabile to rarely quartzose sandstone, calcareous in places, usually interbedded with siltstone; thin beds of hard calcareous siltstone and sandstone. Low-angle cross-bedding and small-scale slumping common, abundant poorly preserved plants. 105-120 m thick in W, up to 300? m in syncline W of Injune	Top formation of Injune Cr Gp. Conformable on Adori Sst in W; or possibly disconformable on Birkhead Fm E of Maranoa Anticline. Recognizable throughout large area in subsurface by high gamma-ray readings on logs	U. Jurassic spores and acritarchs. Probably largely deposited in lakes; cross-bedded sandstone units may have been deposited in small deltas; presence of acritarchs and traces of glauconite suggest occasional marine incursions
Adori Sandstone (Ja)	N-trending belt in SW part of map area; forms low cuestas and strike ridges	Adori Hill 35 km ENE of Tambo (Woolley, 1941; Exon, 1966)	Medium to very thick-bedded cross-bedded white argillaceous sublabile sandstone with pebbly sandstone bands, worm casts and tubes, plant impressions, and clay clasts; minor interbeds of thin-bedded grey to buff siltstone and white claystone; some minor erosion surfaces in formation. 60 m thick; lenses out to SE	Middle formation of Injune Cr Gp in W; lenses out to SE near axis of Maranoa Anticline. Conformable on Birkhead Fm	Indeterminate plants only. Conformable between units containing M. Jurassic spore assemblage below and U. Jurassic assemblage above. Possibly fluvial; cross-beds suggest N or NE provenance
Birkhead Formation (Jmb)	S part of Mimosa Syncline; extends W to Billin Cr and then NNW; mainly low relief with some low cuestas	Along Birkhead Cr near Tambo-Alpha road. Type section from 1880-2244 ft (573.0-684.0 m) in Westbourne 1 (Exon, 1966; Gerrard, 1964)	SW of area: grey carbonaceous siltstone and mudstone, fine to medium lithic sandstone, thin coal seams, rare thin beds of cone-in-cone limestone (120 m), over medium-grained sublabile sandstone with calcareous concretions, gritty and quartz-rich in places in basal 6 m Injune to Billin Cr area: as above with additional 45 m of fine to coarse cross-bedded labile sandstone (Springbok Sst Mbr, Mollan et al., in press) at top. Mimosa Syncline: poorly exposed alternating mudstone and sandstone, with many coal seams up to 1.5 m thick (90 m), underlain by medium to coarse cross-bedded argillaceous calcareous lithic sublabile to labile sandstone, locally conglomeratic near base. 30-60 m thick	Basal formation of Injune Cr Gp. Conformable or locally disconformable on Hutton Sst. Springbok Sst Mbr of Injune/Billin Cr area may be equivalent of Adori Sst. Increase in proportion of calcite in lower unit and coal in upper unit from W and E probably reflects changes in depositional environment	M. Jurassic microflora; probable Jurassic macroflora. Fluviolacustrine changing to lacustrine-paludal in E; mainly fluvial and lacustrine, and rarely paludal, in W

TABLE 15 (continued)

Rock Unit (map symbol)	Distribution and Topography	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Hutton Sandstone (Jlh)	Broad sinuous belt across S part of map area; low sandy plains and rounded hills	Near Hutton Cr 19 km ENE of Injune (Reeves, 1947; Whitehouse, 1955)	Medium-grained poorly sorted cross-bedded feldspathic? argillaceous sublabile sandstone grading up into mainly fine thick-bedded massive well sorted quartzose sandstone; minor beds of siltstone, mudstone, and pebble conglomerate; mudgalls common in sandstone, particularly near base; thin-bedded sandstone and mudstone near top. 120-225 m thick	Conformable on Evergreen Fm. Thickest in synclines and thinnest over structural highs where lower sandstone is generally richer in quartz	Plants, logs, and one species of pelecypod in one bed of unknown affinities. Palynological data suggest mainly L. Jurassic age, but may extend into M. Jurassic. Fluvial? or brackish?; more reworking in upper part
Evergreen Formation (Undifferentiated) (Jle)	Broad sinuous belt across S part of map area to W margin; mainly soil-covered plains and scarps on sandstone members	Type area and section in outcrop and boreholes 40 km NNE of Injune	Fine to medium light grey flaggy micaceous feldspathic? labile to sublabile sandstone grading up into green massive lithic sandstone, locally ripple-marked, cross-bedded, and/or calcareous; thin-bedded and fissile siltstone and mudstone; hard white flaggy micaceous argillite; thin coal seams; thin beds of concretionary limonite; calcareous mudstone. Includes 3 members described below. Max thickness of 168 m in E; 144 m in type area; 120 m in W	Conformable on Precipice Sst; locally overlaps Precipice Sst in E. One member E of Mimosa Syncline and two members to W. To NW, Boxvale Sst Mbr thickens and eventually is sole representative of formation	Rare freshwater? pelecypods, abundant plant remains, spores, and acritarchs, which indicate L. Jurassic age. Acritarchs associated with oolite member and Westgrove Ironstone Mbr. Most of Evergreen Fm deposited in freshwater lake. Lower part of Boxvale Sst Mbr possibly deposited in streams or deltas around W margin of lake. Middle and upper parts (Westgrove Ironstone Mbr) and oolite member possibly deposited during short-lived marine incursion. Lensing out of Westgrove Ironstone and oolite member to N suggests easterly connexion to open sea
Oolite Member (Jlo)	Sinuous thin belt along E limb of Mimosa Syncline; low distinct scarps and soil-covered slopes	Informal unit. Best exposures 38 km SW of Cracow	Chamositic mudstone, as in Westgrove Ironstone Mbr, in beds 5 cm-1 m thick; thin-bedded ferruginous sublabile sandstone; grey fissile and massive red-brown ferruginous mudstone; ironstone beds produced by ferruginization of thin-bedded sediments. 6-12 m thick	Member near top of Evergreen Fm in E limb of Mimosa Syncline. Probably equivalent to upper part of Boxvale Sst and Westgrove Ironstone Mbr	
Boxvale Sandstone Member (Jlb)	Broad sinuous belt in SW from W margin to axis of Mimosa Syncline; prominent scarps and plateaux	Along Dawson R, N to NE of Injune (Reeves, 1947)	Ripple-marked thin-bedded flaggy and micaceous very fine quartzose sandstone, with worm tubes and interbeds of grey micaceous siltstone, predominant in upper part; thick-bedded cross-bedded poorly sorted argillaceous quartzose sandstone dominant in lower part; middle part includes thinly bedded siltstone, fine sublabile and quartzose sandstone, coal, green labile sandstone, and bedded ironstone (possible altered chamositic mudstone). Max thickness 90 m; lenses out to E	Member in Evergreen Fm, which is conformably overlain by Westgrove Ironstone Mbr. Middle and upper units may be time equivalents of lower part of oolite member. In NW conformable between Precipice and Hutton Ssts	

TABLE 15 (continued)

Rock Unit (map symbol)	Distribution and Topography	Type Area and Main References	Lithology and Thickness	Structure and Relationships	General Remarks
Precipice Sandstone (Jlp)	Wide to thin sinuous belt along margin of Great Artesian Basin and outlier to N near Bluff; forms cliffs, scarps, gorges, buttes, plateaux, and mesas with sandy soil cover	In Precipice Cr and adjacent tributaries of Dawson R (Whitehouse, 1952, 1954)	Thick-bedded cross-bedded poorly sorted quartzose sandstone with muscovite flakes, plant impressions, quartz-pebble bands; very coarse sandstone to fine conglomerate particularly near base; thin-bedded lithic sublabile sandstone, laminated micaceous siltstone and white flaggy argillite, thin coal seams and carbonaceous shale near top in SE; includes more lutite in subsurface to S. Thickness ranges from 30 m in SE to 150 m in NW; thinner on anticlines than in synclines	Unconformable on Permian and Triassic units; angular unconformity in E and centre and disconformity in W. Grades up into Evergreen Fm. Outliers to N indicate original depositional area extended well N of present margin of Great Artesian Basin	L. Jurassic spore assemblage in carbonaceous interbeds. Mainly fluvial; cross-bedding measurements indicate mainly E transport; thinning and local cross-bedding directions suggests depositional area bounded to E
Westgrove Ironstone Member (Jlw)	Crops out in thin sinuous belts between Boxvale Sst and Hutton Sst from W limb of Mimosa Syncline to near W margin of map area; low scarps and soil-covered slopes	Type section in shallow boreholes beside Carnarvon Developmental Road, 40 km NNE of Injune (Mollan et al., in press)	Concretionary ironstone, oolitic in places, chamositic? mudstone, mudstone, siltstone. 9-24 m thick; lenses out to N	Member at top of Evergreen Fm W of Mimosa Syncline	

TABLE 16. IGNEOUS ROCKS

Rock Unit (map symbol)	Distribution and Topography	Lithology and Main References	Geological Age	Isotopic Age* (approx.)	Relationships
(Tb)	Widespread sheets and outliers in SE Clermont Stable Block, Denison Trough, N part of Bowen Basin, and Mimosa Syncline; scattered outcrops elsewhere. Forms plateaux and grassy downs	Mainly flood basalts: tholeiitic and alkalic olivine basalt and rare trachyandesite and hawaiite flows; mostly fine-grained, slightly porphyritic, rarely vesicular; remainder vesicular with amygdales of zeolites, calcite, and chalcedony. Plugs, dykes, and rare sills of basalt, gabbro, diorite, olivine teschenite, and analcite basanite. Minor tuff, volcanic conglomerate, and freshwater sediments. (Malone et al., 1964, 1966, 1969; Veevers et al., 1964a,b; Olgers et al., 1966; Jensen et al., 1966; Mollan et al., 1969, and in prep.)	Tertiary. No accurate stratigraphic control. Some probable Tertiary plants in underlying sediments in places	33-20 m.y. (Probably many separate intrusions and extrusions)	Interbedded with, overlain by, or overlying Tertiary sediments in places. Basalts of Clermont Stable Block and Denison Trough genetically related to Peak Ra and Minerva Volc and Hoy Basalt. Intrusive into or unconformable on pre-Tertiary rocks
Hoy Basalt (Th)	Scattered plugs NW of Anakie form prominent conical hills, generally aligned along NNE trends	Columnar jointed porphyritic olivine basalt, minor olivine dolerite and gabbro, generally containing inclusions of anorthosite, peridotite, gabbro, pyroxenite, acid plutonic rocks, corundum, spinel, pyroxene, and feldspar. Remnants of associated basalt flows. (Veevers et al., 1964a)	Tertiary		Probably related to flood basalts. Intrudes Retreat Granite, Anakie Metamorphics, and Drummond Gp
(Tv)	Isolated areas in N part of basin, mainly near W margin of Connors Arch and E of arch, and at Cape Hillsborough. Form plateaux with vertical cliffs, high mountainous country, and rounded or conical hills	Mainly acid to intermediate flows, pyroclastics, plugs, and dykes. Fine-grained porphyritic, rarely non-porphyritic, rhyolite with contorted flow laminae, interbedded with rhyolite breccia, tuff, and agglomerate; flow-banded porphyritic trachyte and soda-trachyte flows and sills; dacite flows with columnar jointing in places; sodic microgranite plug; basaltic and andesitic volcanics; welded tuff. Minor shale and sandstone interbedded with pyroclastics at Cape Hillsborough. (Malone et al., 1966; Jensen et al., 1966)	Tertiary spores and dicotyledonous leaves at Cape Hillsborough.		Overlie Tertiary basalt and Tertiary sediments. Intrusive into or unconformable on pre-Tertiary rocks
Peak Range Volcanics (Tp)	Peak Ra NE and E of Clermont. Form prominent steep hills and mountains	Trachyte, quartz trachyte, peralkaline rhyolite plugs, dykes and flows in S part of Peak Ra; rhyolite plugs, flows, and dykes, some plugs with pitchstone selvages, rare phonolite plugs in N part of Peak Ra (Mollan, 1965)	Tertiary		Acid to intermediate differentiates of alkali basalt flows of Peak Ra area

* Approximate isotopic ages based on data supplied by A.W. Webb.

Table 16 (continued)

Rock Unit (map symbol)	Distribution and Topography	Lithology and Main References	Geological Age	Isotopic Age* (approx.)	Relationships
Minerva Hills Volcanics (Tr)	N of Springsure. Prominent peaks, ridges, mesas, and rounded hills with relief of up to 240 m	Plugs, domes, and dykes of porphyritic soda-rhyolite and quartz trachyte, flow-banded, autobrecciated, columnar jointed; intruding but co-magmatic with flows of basalt, trachyte, and trachybasalt, basaltic ash, pumice, scoria, acid agglomerate. (Veevers et al. 1964a; Mollan et al., 1969)	Tertiary	28-24 m.y. (Probably several periods of intrusion and extrusion)	Probably acid differentiates of basaltic magma, similar to parent magma of Peak Ra Volc
Tabor Gabbro (Tt)	150 km NW of Injune	Stocks and one sill of teschenitic olivine micro-gabbro. (Mollan et al., in press)	Probably Tertiary		Intrudes Hutton Sst
(K/Tv)	On and W of Connors Ra and Broadsound Ra. On ranges: steep-sided dissected plateaux and hills. W of ranges: rugged broken hills, circular or elongate in plan	Fine and even-grained, rarely porphyritic, rhyolite with smooth or contorted flow banding, rhyolite autobreccia, agglomerate, and lapilli tuff; massive porphyritic, locally flow-banded, dacite and trachyte, minor toscanite flows and pyroclastics; includes plugs and dykes of same rock types in places. (Malone et al., 1969)	Cretaceous or Tertiary. Structural deformation and geomorphology suggest they may be pre-Tertiary		Unconformable on or intrusive into Carboniferous, Permian, and Triassic rocks. Possibly related to Cretaceous or Tertiary (K/Ti) intrusive activity
(Tv) (=K/Tv)	On Cape Conway and islands in NE part of map area. Mainly rugged cliff-bounded islands	Acid to intermediate, water-laid ash-fall tuff and agglomerate, well bedded in places; andesite and rhyolite flows and rhyolite flows; arkosic carbonaceous conglomeratic sediments. Intermediate to acid dykes. (Clarke et al., in press)	Cretaceous. May include rocks of different ages	112 m.y. (sample from Cape Conway only)	Intruded by granites similar to some giving probable late L. Cretaceous isotopic ages
(K/Ti)	High hill 16 km SW of Baralaba	Massive fine to coarse trachyte stock, some dykes. (Olgers et al., 1966)	Certaceous or Tertiary	70 m.y.	Intrudes Gyranda Fm
(K/Ti)	Long crescentic ridge 110 km E of Clermont	Medium-grained trachysyenite sill with associated trachyte dykes. (Malone et al. 1969)	Probably as above		Associated dykes intrude Blackwater Gp
(Mi)	Small to medium-sized intrusives near Mackay. Mainly subdued topography, but some smaller bodies form high rugged hills	Mainly diorite, microdiorite, and microgranodiorite cut by many dark fine-grained dykes; coarse and medium-grained granite; granophyre with dolerite and rhyolite dykes. (Jensen et al., 1966)	May include rocks of several ages		Intrude Permian or Devono-Carboniferous rocks. Overlain by Tertiary volcanics

Table 16 (continued)

Rock Unit (map symbol)	Distribution and Topography	Lithology and Main References	Geological Age	Isotopic Age* (approx)	Relationships
(Ki)	Small intrusion near Cape Hillsborough	Coarse pink alkali granite with flat sheet jointing. (Clarke et al., in press)	Late L. Cretaceous	110 m.y.	Intrudes Campwyn Beds
(Ti) (=K/Ti)	On some islands in NE part of map area	Massive medium-grained pink or grey granite, cut by thick acid dykes and thin irregular basic dykes; flat sheet jointing common. (Clarke et al., in press)	Probably late L. Cretaceous		Correlated with Cape Hillsborough granite on lithology
(Ki)	Small to medium-sized intrusions in Nebo Synclinorium and N part of Collinsville Shelf. Mainly subdued topography surrounded by high hills of metamorphosed sediments	Plutons up to 9 km across, laccoliths, sills, and dykes; possibly members of differentiated suite; mainly fine-grained porphyritic hornblende granodiorite, alkali granite, microgranodiorite, syenite, leucodiorite, leucocratic anorthite gabbro, and dolerite dykes. (Malone et al., 1964, 1966)	Early L. Cretaceous. Probably intruded during folding of Nebo Synclorium	130-120 m.y. (probably more than one intrusive event)	One body intrudes Carborough Sst; others intrude U.Permian Blackwater Gp. Generally conformable with structures; low-grade but extensive contact metamorphism
Mount Barker Granodiorite (Kgm)	83 km W of Mackay. Mainly forms upland valley; some high hills capped by metamorphics	N-trending biotite hornblende granodiorite; some high-grade contact metamorphic rocks preserved on top of hill of granodiorite in one place. (Malone et al., 1964; Isbell, 1955)	Early L. Cretaceous	125 m.y.	Intrudes Lizzie Cr and Connors Volc. Probably related to Cretaceous intrusives (Ki) of Nebo Synclinorium
Bundarra Granodiorite (Kgb)	130 km NE of Clermont. Occupies area of low relief surrounded by hills of metamorphosed sediments	Leucocratic granodiorite ranging to alkali granite and syenite with increase of hornblende. (Malone et al., 1964, 1969; Veevers et al., 1964b; Jensen et al., 1966)	Early L. Cretaceous		Occupies core of dome in Back Cr Gp and Blackwater Gp. Correlated with and possibly genetically related to Cretaceous intrusives (Ki) of 130-120 m.y. age
(P-Mi)	13 km SE of Collinsville	Small hornblende granodiorite to diorite stock intruding Lizzie Cr Volc. (Malone et al., 1966)	Post-L. Permian		Probably related to early L. Cretaceous intrusions
(P-Mi)	Several small intrusions between Broad Sound and Mackenzie R and Fitzroy R	Gabbro stocks intruding serpentinite; gabbro stocks and sill intruding Rookwood Volc and Rannes Beds; diorite intruding Back Cr Gp; granite stocks intruding L. Palaeozoic? metamorphics. (Malone et al., 1969)	Permian or younger	240 m.y. (sample from one intrusion only; age of recrystallization, probably)	Probably mainly related to U. Permian intrusive activity; some may be younger
(C-Mi)	29 km NE of St Lawrence	4 small intrusions ranging from adamellite to granodiorite; probably intrude Carmila Beds. (Malone et al., 1969)	Permian? or younger		Lithologically like L.Cretaceous part of Urannah Complex

Table 16 (continued)

Rock Unit (map symbol)	Distribution and Topography	Lithology and Main References	Geological Age	Isotopic Age* (approx.)	Relationships
(C-Mi)	In Connors Ra and Broadsound Ra	Granodiorite, adamellite, alkali granite, granite, monzonite, gabbro; trachyte and dolerite dykes; some intrusions are complex, others consist of one rock type. All intrude Connors Volcanics. (Malone et al., 1969)	Carboniferous to Mesozoic	305 m.y. (sample from one intrusion only; possibly includes other ages of intrusion)	Similar to and probably connected with Urannah Complex; probably includes intrusions of similar ages
(C-Mi)	East of N-flowing Fitzroy R	Large adamellite stock intruding Carboniferous and older sediments	Post-Carboniferous		
(C-Mi)	32 km S of Marlborough	Isolated granodiorite which may be connected with large Permian intrusions to E. (Malone et al., 1969; Kirkegaard et al., 1966, and in prep.)	Unknown		Possibly emplaced during extensive U. Permian period of intrusive activity
(C-Mi)	Poorly exposed area E of Broad Sound	Acid plutonic rocks probably related to Polygon Granite to E. (Kirkegaard et al., 1966, and in prep.)	Unknown		
Urannah Complex (C-Mr)	Occupies bulk of Connors Arch from N boundary of map area to lat 22°S. Varied topography: mainly rugged, with many upland valleys	Fine to very coarse massive or foliated to gneissic, locally porphyritic and/or xenolithic, diorite; adamellite and granodiorite; large amphibolite xenoliths in diorite and granodiorite; porphyritic, graphic, and leucocratic granite and pegmatite, aplite dykes; dacite, acid porphyry dykes; stocks up to 1½ km across of gabbro grading into hornblendite; green porphyritic andesite and microdiorite dykes up to 6 m across; basalt and dolerite dykes. (Malone et al., 1964, 1966; Jensen et al., 1966)	Ranges from Carboniferous or older? to Cretaceous	311-290 m.y. (see text). Probably younger intrusions also	Complex probably mainly Carboniferous. Some plutonic rocks and most of dykes younger. Oldest rocks intrude Connors Volc.
(C-Mr)	Not delineated within complex	Hornblende-biotite adamellite (see Thunderbold Granite, Paine et al., 1970). Hornblende-biotite adamellite and granodiorite, microgranite. (In part Hecate Granite, see Paine et al., 1970)	L. Permian L. Cretaceous	265 m.y. 125 m.y.	Probably discrete bodies within complex Probably discrete bodies within complex
Auburn Complex (C-Ma)	Core of Auburn Arch, in SE part of map area. Poorly lateritized in places	Fine to medium-grained granodiorite, locally porphyritic, microgranodiorite, minor diorite and monzonite; dykes of dacite, andesite, and aplite. (Mollan et al., in press)	Mainly Carboniferous in map area	311 m.y.	Includes intrusives of U.Permian age E of map area. Oldest rocks intrude pre-Permian part of Camboon Andesite
(C-Rv)	SW of Rannes E of Theodore	Quartz porphyry, rhyolite, aplite. Part of pre-Permian Camboon Andesite	Unknown Carboniferous or older		Mainly intrusive

Table 16 (continued)

Rock Unit (map symbol)	Distribution and Topography	Lithology and Main References	Geological Age	Isotopic Age* (approx.)	Relationships
(Pui)**	Around Marlborough	Biotite adamellite and granodiorite with basic xenoliths	U. Permian	235 m.y.	Intrudes serpentinite (Pzs) and metamorphics (Pzl).
(Pui)**	N. of Marlborough	Diorite, quartz diorite, microdiorite, gabbro, hornblende gabbro, granite	U. Permian	248-240 m.y.	Intrudes Carmila Beds; basic intrusion followed by more acid intrusion
(Pui)**	72 km S of Marlborough	Adamellite, minor diorite	U. Permian	240 m.y.	Intrudes Rookwood Volc
(Pzs)	Large area around Marlborough. High rugged topography	Massive serpentinite, schistose near fault contacts, contains blocks of microdiorite. (Malone et al., 1969; Kirkegaard et al., 1966, and in prep.)	Permian		Intrudes metamorphics (Pzl) and L. Permian sediments E of map area. Intruded by U. Permian plutonic rocks
(Plx)	W to SW of Eungella. High prominent rounded ridges	Diorite, microdiorite, gabbro, and microgabbro sills or laccolith. (Malone et al, 1964)	L. Permian		Intruded into and possibly intrusive equivalents of Lizzie Cr Volc
(Ci)	In NW part of map area. Mainly occupy valleys	Granite, granodiorite, adamellite, xenolithic in places, cut by aplite and other fine-grained acid dykes. (Malone et al., 1966; Paine et al., 1970)	U. Carboniferous	285 m.y.	Intrudes Bulgonunna Volc and unconformably overlain by Lizzie Cr Volc
(D/Ci)	In NW part of map area, near lat 21°S	Adamellite, biotite-hornblende adamellite and granodiorite, hornblende granodiorite and tonalite; diorite; jointed, faulted, xenolithic, contain many large roof pendants of contact metamorphosed sediments. (Malone et al., 1964,1966; Paine et al., 1970)	Devonian or Carboniferous	330; 295-290 m.y. (see text)	Intrude Ukalunda Beds; may be unconformable beneath Drummond Basin sequence
Retreat Granite (Dgr)	Large area NE of Emerald. Mainly subdued topography	Granodiorite to adamellite, minor granite and monzonite; small amounts of gabbro, diorite, quartz diorite, andesite, and tonalite. (Veevers et al., 1964a, b)	Devonian	365 m.y.	Intrudes Anakie Metamorphics. Unconformably overlain by Silver Hills Volc
(Pzg)	Small area 45 km W of Springsure	Poorly exposed granite. (Mollan, et al., 1969)		450 m.y.	Intrudes? Anakie Metamorphics
(Pzr)	Near Maranoa R 100 km NW of Injune	Sheared diallage-rich gabbro cut by tremolite and chlorite veins; associated with tremolite and chlorite rock. (Mollan et al., in press)	Ordovician or older		Unconformably overlain by Precipice Sst
Ravenswood Granodiorite (Pzi)	NW corner of map area	Hornblende-biotite granodiorite, adamellite, microgranodiorite, some microgranite. (Paine et al., 1970)	Silurian		Intrudes Mt Windsor Volc. Part of N basement to Drummond Basin

** These intrusions are related to extensive U.Permian igneous activity mainly centred to E and SE of map area (Malone et al., 1969; Kirkegaard et al., 1966, and in prep).

APPENDIX

ISOTOPIC DATING OF THE IGNEOUS ROCKS OF EASTERN QUEENSLAND

by

A.W. Webb*

METHODS

Isotopic ages were measured by both the K/Ar and Rb/Sr methods. The K/Ar determinations form the bulk of the work, and the intrusive rocks were collected with a view to suitability for K/Ar analysis. Consequently, most of the samples contain biotite and/or hornblende. Only fresh unweathered samples were collected, and most were obtained by drilling and blasting large tors.

Potassium was determined as total potassium by flame photometry (Cooper, 1963; Cooper et al., 1966), and the percentage ^{40}K calculated from the measured atomic abundance of this isotope in natural K. ^{40}Ar was measured by isotope dilution (McDougall, 1966). ^{87}Rb and ^{86}Sr were measured by isotope dilution (Compston et al., 1965), and the present day $^{87}Sr/^{86}Sr$ value by direct mass spectrometry on unspiked Sr separations, and also calculated in the process of measurement of ^{86}Sr. The decay constants and natural isotopic abundances used in the calculation of ages are as follows:

$^{40}K = 0.584 \times 10^{-10} yr^{-1}$

$^{40}K = 4.72 \times 10^{-10} yr^{-1}$ (Aldrich & Wetherill, 1958)

$^{40}K = 1.19 \times 10^{-2}$ atom % of total K

$^{40}Ar = 99.60$ atom % of atmospheric Ar

$^{38}Ar = 0.063$ atom % of atmospheric Ar

$^{36}Ar = 0.337$ atom % of atmospheric Ar (Nier, 1950)

$^{87}Rb = 1.47 \times 10^{-11} yr^{-1}$ (Flynn & Glendenin, 1959)

$^{88}Sr/^{86}Sr = 8.3752$ (Nier, 1938)

$^{85}Rb/^{87}Rb = 2.5995$ (Shields & Garner, 1963)

* Formerly of the Bureau of Mineral Resources

The coefficient of variation (standard deviation expressed as a percentage) of the potassium analyses, based on the variation of individual measurements about the mean, for over 100 duplicate analyses is 0.24 for biotite and 0.33 for hornblende. The precision of the argon measurements, calculated in the same manner as for potassium, is 0.90. Much of this error is due to the uncertainty in the argon tracer calibration. For a normal K/Ar mineral age determination (duplicate K, single Ar) where the grain purity exceeds 98 percent, the probable error at the 95 percent confidence level is $\pm$ 2 percent, ignoring all uncertainties in decay constants and isotopic abundances. The limits of error in a single K/Ar age are found to be approximately equal to the standard deviation of individual K/Ar ages measured on a number of samples from the one intrusion. Such agreement is presumed to be confirmation that the samples dated were taken from a single population, and that the mean age is geologically meaningful. Where the standard deviation of the measured ages of a group of related rocks is significantly greater than the expected error, it would be interpreted as a smearing of the true age by some geological effect. The limits quoted for the K/Ar ages of groups of related rocks in this paper are the standard deviation of the mean.

Rubidium isotope ratios were measured with a Metropolitan-Vickers Mass Spectrometer, type MS2-G (Compston et al., 1965). A single ^{84}Sr-enriched tracer was used for the strontium determinations, and the ratios measured on a Nuclide, 60° sector, 12-inch radius of curvature mass spectrometer. The precision of measurement of the $^{87}Sr/^{86}Sr$ ratios with the Nuclide was found to be greater than with the MS2, especially when using the ^{84}Sr-enriched spike, and was usually comparable to that of the directly measured ratios of unspiked samples.

The total rock data for samples from the one intrusion or formation have been analysed graphically as a plot of $^{87}Sr/^{86}Sr$ against $^{87}Rb/^{86}Sr$ (Nicolaysen, 1961). The slope of the straight line (isochron) fitted to these points by a least squares method assuming errors in both parameters (McIntyre et al., 1966) is proportional to the age of the samples, and the intercept on the $^{87}Sr/^{86}Sr$ axis is the strontium isotopic composition at the time of formation of the samples. A value of 0.10×10^{-6} was used for the variance in the measurement of $^{87}Sr/^{86}Sr$ in the regression of the data, because of the greater precision attained using the Nuclide mass spectrometer. The Rb/Sr age and initial ratios are quoted at the 95 percent confidence level.

SIGNIFICANCE OF MINERAL AGES

When comparing or interpreting ages measured by different methods, or by the one method on different minerals, it is necessary to know what these ages represent. For the simplest model that of a lava or a quickly cooling pluton that has not been reheated, the age of a mineral will indicate the time at which the radiogenic daughter product began to be retained in the mineral. Experimental and field studies made on the conditions under which argon will diffuse from minerals (Evernden et al., 1960; Hart, 1964) have indicated that above about 300°C argon will be lost from mica as rapidly as it is generated. At 200°C, the diffusion rate is sufficiently low that no argon is lost during the relatively short time in which the extrusive and high-level intrusive rocks cool from 200°C to surface temperature. The K/Ar mica age is therefore the time that has elapsed since the mineral cooled below about 200°C, and for rocks of pre-Tertiary age, this time is experimentally indistinguishable from that since the extrusion or emplacement occurred. These values of temperatures were derived by interpolation between temperatures used in short-term laboratory studies, and the extrapolation of these data to deduce diffusion behaviour over long intervals of geological time may introduce a large uncertainty.

It is also assumed that the different activation energies and diffusion rates for argon in different minerals will lead to some minerals becoming closed systems, with respect to argon, at higher temperatures than for others. Thus, where cooling is slow, it might be expected that cogenetic minerals will have distinctly different 'ages'. Conversely, when cooling is rapid, no such differences are expected, and agreement in age between cogenetic minerals (most commonly biotite and hornblende) is usually accepted as an indication of rapid cooling and no subsequent thermal history.

Outgassing of radiogenic argon from minerals may occur by heating during regional or contact metamorphism. The effects of contact metamorphism are usually restricted to a relatively narrow zone in the country rocks about the younger intrusion (Hart, 1964) where zones analogous to metamorphic isograds can be drawn showing the distances at which different minerals are completely outgassed of argon. Hart (1964) reported that under conditions of thermal metamorphism, hornblende retained significantly greater amounts of radiogenic argon than did biotite in the same rock. Aldrich et al. (1965) believed the K/Ar age measured on hornblende to be equal to that measured by the Rb/Sr method on muscovite and K-feldspar. These authors concluded that in rocks that had undergone metamorphism, the normal order of increasing mineral age is (1) biotite, K/Ar; (2) biotite, Rb/Sr; (3) muscovite, K/Ar; (4) hornblende, K/Ar, muscovite and K-feldspar, Rb/Sr. Hanson & Gast (1967) arrived at similar conclusions as to the relative stability of these minerals under conditions of contact metamorphism. Thus, when hornblende or muscovite K/Ar dates are significantly higher than those of cogenetic biotite, the first assumption is that the rock has suffered a thermal metamorphism.

Diffusive loss of radiogenic strontium can also occur, but in this case, the ^{87}Sr may migrate into another mineral phase of the rock. While the Rb/Sr mineral ages may reflect the cooling or metamorphic history of the rock, in a similar fashion to the K/Ar ages, the rock as a whole may have remained a closed system with respect to rubidium and strontium and indicate an age greater than that shown by some of its mineral components (Compston & Jeffery, 1959).

Although there appears to be little published information on laboratory investigations of the diffusion rates of ^{87}Sr in biotite, the frequent correspondence between Rb/Sr and K/Ar ages on this mineral from all environments suggests that strontium diffuses at similar rates and at the same temperatures as does argon. From measurements made on biotites from the Alpine Fault Zone of New Zealand, Hurley et al. (1962) concluded that the diffusion coefficients for strontium and argon in biotites are similar at low temperatures.

The ideal total rock age is determined on a suite of rocks with varying Rb/Sr ratios, which differentiated from an isotopically homogeneous parent magma. The age measured is the time of separation of the different phases from the parental magma and could be distinct from the time at which certain minerals in the differentiated fraction cooled to near surface temperatures. The difference between the two ages will depend to a large degree on the tectonic environment at the time and place of formation and intrusion of the magma. Volcanic and high-level intrusive rocks would not be expected to reveal any significant age difference between mineral and total rock determinations. However, in high-grade metamorphic terrains the difference may be considerable.

The sequence of increasing retentivity of radiogenic daughter isotope in different minerals proposed by Aldrich et al. (1965) may be taken as an approximation to the normal behaviour of these minerals, although departures from it are not uncommon. Arriens et al. (1966) described examples where the Rb/Sr and K/Ar biotite ages exceeded the Rb/Sr K-feldspar ages, and evidence will be given in a later section to show that under certain metamorphic conditions, the argon retentivities of biotite and hornblende are similar.

DISCUSSION OF RESULTS

K/Ar mineral ages have been measured on granitic rocks throughout eastern Queensland, and a smaller number of Rb/Sr total rock and mineral ages were determined on granites and volcanics from selected regions. The analytical data are presented in Tables 1-15.

The K/Ar ages indicate two major periods of granitic emplacement. The older epoch was protracted, covering a time interval of 150 million years (m.y.) during which several magmatic pulses have been recognized. This was followed by 100 million years of quiescence, until the second period of granite emplacement, over an interval of about 15 million years, took place. Within the older magmatic epoch, a histogram of the K/Ar ages would reveal several apparent maxima of intrusive activity, the time interval between many of these maxima being just greater than the expected experimental error of the K/Ar method. The agreement in age between cogenetic minerals increases the credibility that the peaks of K/Ar dates record phases of igneous activity. These episodes occurred 360, 305, 285, 270, 250, 235, and 220 million years ago, some of the phases occurring in widely separated areas, and many of them in the one area. In the younger epoch, during the early Cretaceous, the K/Ar dating indicates two phases of granitic intrusion - 125 and 115 to 110 million years ago.

The Rb/Sr data show this interpretation of the geological history to be too complex, and that many of the apparent intrusive phases recorded by the K/Ar dating are the result of loss of radiogenic argon , for example, in the Connors Arch, where the K/Ar dating indicates episodes of intrusion at 305, 285, and 270 million years ago, the Rb/Sr analyses show that the 285, and many of the 270-m.y. granites were part of the 305-m.y. period of intrusion. The wide extent of the 305-m.y. phase has become more apparent, while the 270-m.y. phase, which on the K/Ar evidence was extremely widespread, has been reduced considerably.

Nevertheless, there may have been as many as seven periods of intrusion during the older epoch of magmatic activity, the most widespread occurring during the Carboniferous and the late Permian. The former may be correlated with granitic intrusions in New South Wales (Evernden & Richards, 1962) and probably in north Queensland (Richards et al., 1966), while the latter extended into the New England district of New South Wales (Evernden & Richards, 1962; Cooper et al., 1963; Binns & Richards, 1964).

The intrusions, in general, become younger from west to east, with Devonian granites in the Anakie Inlier, Carboniferous and Permian intrusions in the Connors and Auburn Arches, and Triassic and Cretaceous granites at the coast. The western limits of the regions of Upper Permian and Triassic intrusions are remarkably sharp, although older intrusions are known to occur to the east of these boundaries, e.g. the Devonian granites at Mount Morgan within the Upper Permian limits, and the pre-Triassic granite at Kilkivan (Denmead, 1945) east of the Triassic limit.

Throughout the whole region, the intrusive and extrusive rocks have low and reasonably consistent values of initial $^{87}Sr/^{86}Sr$, of the order 0.7035 to 0.7050. This is comparable with the value measured on many present day oceanic and continental basalts, and indicates a possible subcrustal source for the igneous rocks.

The ages adopted for the sections of the geological time scale referred to in this paper are set out below:

Jurassic/Cretaceous boundary	135 m.y. (Casey, 1964)
Lower Triassic/Middle Triassic boundary	220 m.y. (Webb & McDougall, 1967)
Permian/Triassic boundary	230-235 m.y. (Webb & McDougall, 1967)
Carboniferous/Permian boundary	280 m.y. (Francis & Woodland, 1964)
Devonian/Carboniferous boundary	362 m.y. (McDougall et al., 1966)

Western Area - Anakie Inlier

In the southern and central regions of the Anakie Inlier the Anakie Metamorphics are intruded by the Retreat Granite. This granite is overlain by volcanics and sediments of late Devonian age (Veevers et al., 1964). A single K/Ar age of a muscovite from the metamorphics west of Clermont indicates a minimum age of 450 m.y. (Table 1) for the final phase of metamorphism of this unit. Fourteen dates on the Retreat Granite (Table 1) have a mean age of 359 $\pm$ 2 m.y. This date is Devonian to Carboniferous, and therefore at variance with the known field relations. The possibility that some argon loss has occurred, despite the internal agreement between the K/Ar ages, cannot be discounted.

In the northern part of the inlier, granites of two ages have been recognized in the field. One group of granites, in the Ukalunda/Mount Wyatt area, intrudes fossiliferous Middle and possibly Upper Devonian sediments, and is overlain by the Lower Carboniferous Drummond Group (Malone et al., 1966). The younger granites intrude the Bulgonunna Volcanics, which overlie the Drummond Group.

Minerals from three granites of the older group were dated by the K/Ar method (Table 2). An age of 330 m.y. measured on one of these samples (GA5288) may be close to the age of emplacement, but the ages of the other two samples (GA1160, 1161; 295-290 m.y.) are much too young to conform with the field evidence. These ages are similar to those measured on the younger granites of the region, and may be due to argon loss during this later magmatic phase. Alternatively, they may be a part of this phase of intrusion and have not been distinguished from the older granites during the field mapping. A Rb/Sr total rock analysis of sample GA1160 (Table 4) is equivocal. The data fit the isochron for the younger granites to within experimental error; but the enrichment of radiogenic strontium in sample GA1160 is so small, only a slight lowering of the assumed initial $^{87}Sr/^{86}Sr$ ratio would be needed to calculate a late Devonian/early Carboniferous age for this sample.

The Bulgonunna Volcanics and the granites which intrude them are closely related in the field, and the possibility that they are intrusive and extrusive phases of the one magma has been suggested. The Rb/Sr age of the Bulgonunna Volcanics (Table 3) is 287 ± 12 m.y., and all variance in fitting the isochron can be attributed to experimental error. The Rb/Sr analyses of the total rock samples of the granites which intrude the Bulgonunna Volcanics (Table 4) define an isochron of 298 ± 25 m.y. with no variance in excess of that due to experimental error. Two biotites from the granites have Rb/Sr ages of 286 m.y. (Table 4). The regression of the combined total rock and mineral data also defines an isochron to within experimental error, with an age of 286 ± 3 m.y. It may therefore be inferred that there has been no significant loss of radiogenic strontium from the biotites, and the age of 286 m.y. is the preferred one for the granites.

The apparent reversal in the total rock ages of the volcanics and granites when compared with the field observations, is due to the relatively poor precision of the age calculated for the granites. Student's t-test shows that the ages and initial strontium isotopic compositions of the two rock units are not significantly different at the 75 percent level of confidence. If the granites and volcanics are comagmatic and coeval, then it is justifiable to pool the analyses of the two units. When this is done, an isochron of 289 ± 9 m.y. is produced.

The Rb/Sr age is close to the average K/Ar mineral age of 283 ± 1 m.y. for the granites (Table 2). This agreement in age lends support to the field observations that this region has remained stable since the Carboniferous.

The only granitic intrusion known within the Drummond Basin occurs to the west of Anakie. K/Ar mineral ages on two samples of the intrusion (GA1029, 1030) spread between 285 and 300 m.y. (Table 2). Both on field and isotopic evidence, this granite may be correlated with the 285-m.y. old granites to the north.

Northeastern Area - Connors Arch

Carboniferous Intrusions

Bounding the eastern margin of the Bowen Basin for a distance of over 320 km, from Bowen in the north to 80 km south of Mackay, is a continuous belt of granitic rocks. Isolated granitic intrusions occur for another 80 km to the south. These igneous rocks were named the Urannah Complex by Malone et al. (1966). Evidence that some of these intrusions are pre-Permian was noted in the area southeast of Collinsville, where granite boulder conglomerates are interbedded with Lower Permian Lizzie Creek Volcanics. Although phases of apparently different ages were mapped by these authors, the extent of the pre-Permian granite was not known. More detailed mapping of the igneous rocks north of Normanby by Paine et al. (in prep.) has distinguished two dominant lithological and textural types which can be distinguished in places on air-photographs. The most widespread type is sometimes foliated, and may be sheared and recrystallized. It is of dioritic or tonalitic composition and is intruded by swarms of basic dykes which impart a distinctive air-photo pattern. The other type is a massive adamellite with few basic dykes. There are two large intrusions and several smaller bodies of this more felsic type, which is clearly younger than the tonalite. The isolated intrusions in the southern part of the Urannah Complex are massive and granodioritic.

The K/Ar mineral ages measured on samples from the foliated tonalitic types, and the massive intrusions in the south of the complex are listed in Table 5. Three apparent phases of emplacement occurred at 305, 290 to 285, and 270 million years ago, the oldest in the south and the youngest in the north. Agreement in age between cogenetic biotite and hornblende is almost universal, and these ages might be expected to have geological significance.

Rb-Sr analyses were made on total rock and mineral concentrates from members of each of the three K/Ar age groups. The location of these samples is shown in Figure A. The total rock data (Table 6) define an isochron of 288 $\pm$ 31 m.y. and all points fit the isochron within experimental error. The regression of the combined total rock and mineral data shows a large residual variance which is not due to experimental error, and an age of 299 $\pm$ 8 m.y., and suggests that redistribution of rubidium and/or strontium within the mineral phases has occurred. Four biotite determinations, which are independent of slight differences in the choice of initial strontium isotopic composition, indicate ages of 314, 309, 290, and 284 m.y. A comparison of the Rb-Sr and K/Ar ages of these samples is given in Table 7.

Two interpretations of the data are possible.

(1) Because of the low ^{87}Sr enrichment in the total rock samples, the uncertainty in the total rock isochron covers the range of K/Ar ages. Consequently, the regression of the total rock data within experimental error may be fortuitous and the points may actually lie on two or more slightly divergent isochrons. The different ages suggested by the K/Ar measurements could therefore be correct, in general if not in detail.

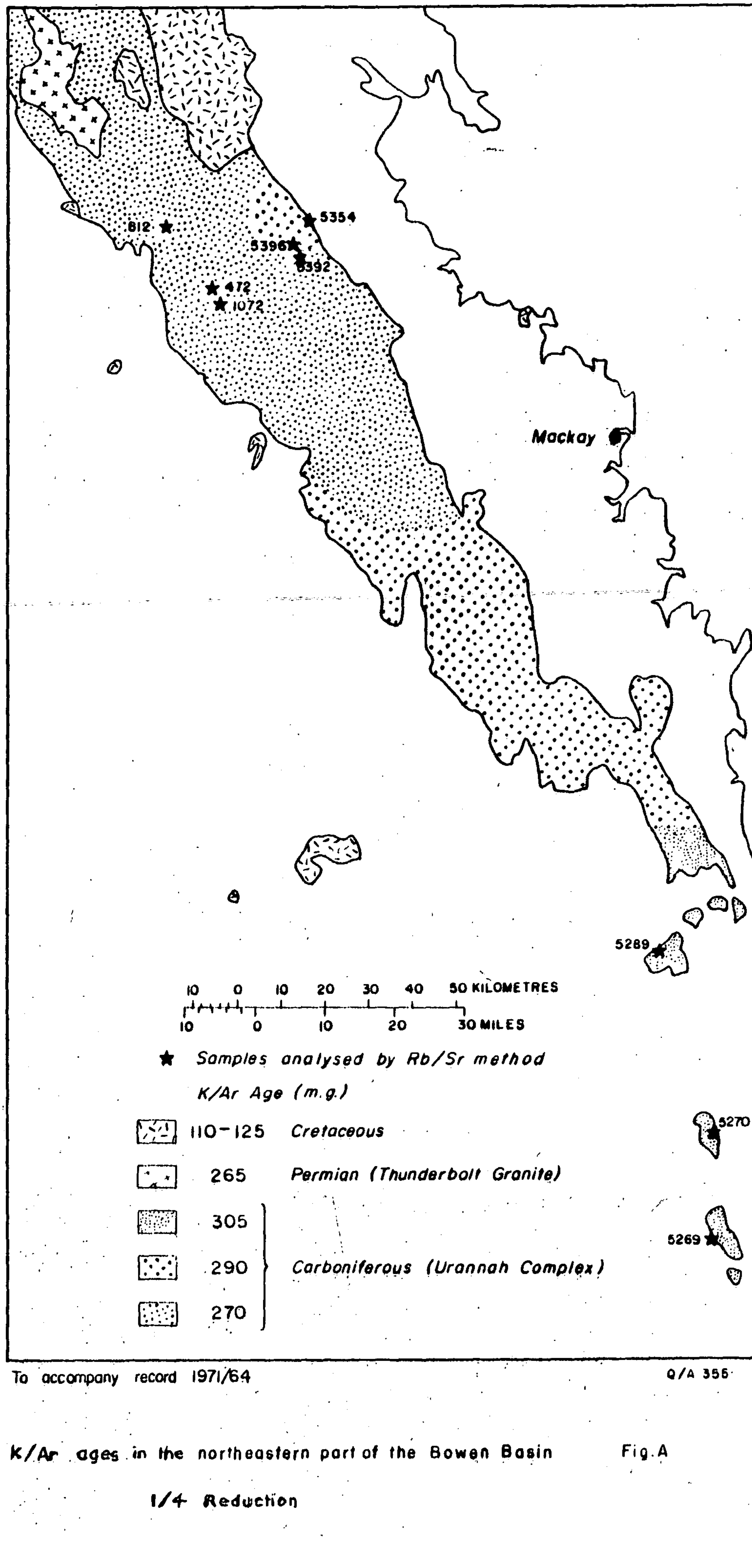
(2) If the regression of the total rock analyses within experimental error is not due to chance, it must indicate that the samples are cogenetic and coeval. The spread in both Rb/Sr and K/Ar mineral ages must then be due to variable leakage of radiogenic strontium and argon during a later thermal event. The general lack of agreement between the mineral ages measured by both methods suggests a smearing effect rather than several distinct phases of intrusion, and this interpretation is considered to be the most likely explanation. Since the large uncertainty in the total rock age cannot be reduced, the most realistic minimum estimate of the age would be the oldest mineral ages measured by one or both methods, that is, 310 to 305 m.y.

The K/Ar mineral ages in the Urannah Complex show a general decrease from 305 m.y. in the south to 270 m.y. in the north (Fig. A), and the spread of dates is thought to be due to the variable regional effects of the events which occurred about 270 m.y. ago. At this time, over 3000 m of volcanics were deposited on the Connors Arch, and many of the dykes cutting the granites may have been feeders for the extrusives. The region subsided while marine sediments were deposited, and at this depth, mineralogical changes which are attributed to a zeolite facies metamorphism took place in the volcanics (Jensen, 1964). As the granites were buried to an even greater depth than the volcanics, the temperatures reached may have been sufficient to cause outgassing of argon and redistribution of radiogenic strontium.

The present outcrop of the Urannah Complex may be interpreted as the result of differential uplift, which was greater in the north than in the south. The isolated intrusions in the south were cupolas of the batholith and the present land surface represents a plane which, in the early Permian, sloped downwards to the north into regions of higher temperature.

Permian Intrusions

A sample from one of the batholiths of massive adamellite in the Urannah Complex (GA473) was reported by Webb et al. (1963) to have a minimum K/Ar age of 270 m.y. This intrusion was named the Thunderbolt Granite by Paine et al. (in prep.). Several samples from this batholith and similar smaller



To accompany record 1971/64

Q/A 355

K/Ar ages in the northeastern part of the Bowen Basin Fig.A

1/4 Reduction

bodies have now been dated by the K/Ar and Rb/Sr methods. The only stratigraphic control on the age of the Thunderbolt Granite is that it intrudes the granites which have been shown to be 305 m.y. old. The mineral ages are shown in Tables 8A and 8B. The mean K/Ar age of 265 ± 1.3 m.y. is supported by the two Rb/Sr measurements. The absence of a significant spread in the mineral ages, the agreement in age between the two methods, and the field observations that the granite is younger than the 305-m.y. old intrusions suggest that the age of 265 m.y. may be meaningful.

A Cretaceous intrusion, the Hecate Granite (Paine et al., in prep.), of greater areal extent than the Thunderbolt Granite also intruded the Carboniferous granites (Fig. A) and had a limited thermal effect on their K/Ar mineral ages. Near Normanby, a sequence of K/Ar biotite ages - 270 (GA5335), 187 (GA5347), 132 (GA5560), and 123 m.y. (GA5331) - has been measured in a direction normal to the contact between the two granites. The oldest date, 270 m.y., although being too young, has not been affected by the Cretaceous intrusion. The two samples with intermediate ages are within a kilometre of the inferred contact and exhibit marked loss of argon. A similar sequence is found in the Cathu State Forest, where ages of 283 (GA5346), 235 (biotite and hornblende) (GA1135), and 117 m.y. (GA1170) were measured. The cases where ages between 260 and 125 m.y. have been found are restricted to the narrow zone surrounding the Cretaceous intrusions. Thus, it is unlikely that the intrusion of the Cretaceous granites could have been responsible for the general lowering of the mineral ages in the Carboniferous granites.

The Urannah Complex is intruded by swarms of dykes which appear to be most abundant in the Carboniferous granites, thereby implying an age between 305 and 265 m.y. for most of the dykes. K/Ar and Rb/Sr analyses of these rocks are given in Tables 9A and 9B. The ages (255-250 m.y.) are younger than that of the Thunderbolt Granite, and suggest that there were several phases of dyke intrusion. At least some of the dykes may have been feeders for the extrusive centres of the Lizzie Creek Volcanics, while other dykes are almost certainly related to Cretaceous intrusions, for example, the swarm surrounding the 115-m.y. old Mount Abbot Igneous Complex (Paine et al., in prep.).

Cretaceous Intrusions

Granitic rocks of Lower Cretaceous age in the Urannah Complex were first reported by Webb & McDougall (1964). Since then, many other intrusions of a similar age have been identified by isotopic dating. These determinations are listed in Table 10.

The Lower Cretaceous intrusions are found in three regions: within the Bowen Basin to the east of the central axis, in the Urannah Complex to the northeast of the basin, and in the coastal strip and offshore islands of the Proserpine area, where Cretaceous volcanic rocks also occur.

Within the Bowen Basin, the intrusions are usually small and hypabyssal, and have a porphyritic texture. They are commonly gabbroic, but granodiorite also occurs.

In the Urannah Complex, the intrusions reach batholithic proportions (the Hecate Granite, Paine et al., in prep.). Here, the dominant rock type is adamellite to granodiorite, similar to the 265-m.y. old Thunderbolt Granite a few kilometres to the west.

In the coastal strip and offshore islands the granites are usually massive leucocratic high-level intrusions. There is frequently a close association between the granites and acid volcanic rocks, and both the intrusives and extrusives in this area are younger (115-110 m.y.) than the other granites (125 m.y.). The close association between the volcanics and granites in the Cumberland Islands was noted in an unpublished report by White & Brown (1963), who suggested a Tertiary age for these rocks. The geology of the area was described by Clarke et al. (1971).

Extrusive Rocks

The Lizzie Creek Volcanics contain a marine fauna near the top of the formation which is probably of late Sakmarian age (Dickins et al., 1964; Malone et al., 1966). In the west, they overlie 285-m.y. old volcanics and granites, and on the time scale of Francis & Woodland (1964), the Lizzie Creek Volcanics are post-Carboniferous.

Three K/Ar measurements made on plagioclase from basalts mapped as Lizzie Creek Volcanics are listed in Table 11. Two of these determinations indicate an approximate age of 270 m.y. for this unit, while the third (GA5374, 229 m.y.) is obviously too young. Either the third sample has lost radiogenic argon, or it does not belong to the Lizzie Creek Volcanics. The age of 270 m.y. determined on the other plagioclase samples lies within the Sakmarian (Smith, 1964). These samples were from the northwestern shelf region and were not subjected to the burial metamorphism that affected the volcanics in the eastern trough. The K/Ar ages are therefore regarded as a reasonable estimate of the age of extrusion of the volcanics.

In the northwestern part of the shelf, the volcanics are predominantly basaltic, but are intruded and overlain by rhyolite. Rb/Sr analyses on several of the acid volcanics (Table 12) have indicated an age of 230 + 15 m.y. for these samples, and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7055 + 0.0007. All analyses fit the isochron within experimental error. The mean value of the age lies close to that of the Permian-Triassic boundary. Samples GA5519 and 5532 are intrusions in the 285-m.y. old granites to the west. The data were not included in the regression of the volcanic samples, but plot on the isochron.

Acid to intermediate volcanic rocks occur in the coastal region east of Proserpine. Some of them are apparently related to granitic rocks which have been shown to be of Lower Cretaceous age. Rb/Sr total rock analyses on the Proserpine Volcanics from the Conway Range area, northeast of Proserpine, are listed in Table 13. The data fit an isochron of 111 $\pm$ 5 m.y. within experimental error. This total rock age is in close agreement with the K/Ar age on the dacite from Carlisle Island, and on the coastal granites, and supports the field observations of White & Brown (1963) that the intrusives and extrusives are closely related in age.

Another indication of the Cretaceous age of the volcanics is given by K/Ar total rock dating of a sample from Pentecost Island (GA5394). The rock is composed essentially of alunite ($KAl_3(OH)_6(SO_4)_2$) and quartz, and the alunite is believed to have been formed by reaction between feldspars and sulphur-bearing vapours or solutions given off during vulcanism. Duplicate determinations of 106 and 96 m.y. indicate a minimum age of late early Cretaceous for the vulcanism.

Southeastern Area

Reid (1930) and Carey & Browne (1938) suggested that the granites of the coastal belt from Townsville to Newcastle were mainly of late Permian age, but it was shown in the preceding section that the granites in the northern part of the belt are Carboniferous, early Permian, or early Cretaceous. In the area from Marlborough south to the New South Wales border granites occur within the Yarrol and Maryborough Basins and in the Auburn Arch and South Coastal High. South of the Surat Basin the northern extension of the New England Batholith crops out.

Devonian Intrusions

The oldest intrusive rocks dated in this study occur at Mount Morgan, where the Mount Morgan Tonalite intrudes the Givetian Capella Creek Beds and is unconformably overlain by the Frasnian Dee Volcanics (Kirkegaard et al., in prep.). The age of the tonalite is therefore closely stratigraphically controlled. Five K/Ar ages measured on hornblende from the tonalite (Table 1) have a mean of 362 m.y. This date is too young for the stratigraphical position of the tonalite (cf. McDougall et al., 1966) and must be explained as due to minor argon loss during some subsequent tectonic or igneous episode.

Plutonic rocks of Devonian age, in the zone of folded Upper Palaeozoic strata, appear to be restricted to the area about Mount Morgan. Granitic rocks within a radius of 40 km of the town are of late Permian age.

Carboniferous Intrusions

On the western side of the Auburn Complex, the granites intrude volcanics which were believed to be of early Permian age (Denmead, 1931, 1946). K/Ar mineral ages (Table 5) on granites in this part of the complex average 300 m.y. (Upper Carboniferous). Rb/Sr total rock analyses on these granites define an isochron of 311 $\pm$ 29 m.y. and all variance can be attributed to experimental error (Table 6). If it is accepted that the granites intrude the volcanics, then the latter cannot be as young as early Permian. Alternatively, there may be two volcanic units present; an older, pre-310 m.y. formation, and a younger, Lower Permian unit. Dear et al. (in prep.) has mapped two volcanic formations - the Torsdale Beds (Carboniferous) and the Camboon Andesite (Lower Permian) in the area north of Cracow.

The similarity of the geological setting of the granites in the Connors and western part of the Auburn Arch suggests that they could be the same age. Student's t-test shows that the Rb-Sr total rock ages of both groups of granites and their initial $^{87}Sr/^{86}Sr$ ratios are not different at the 90 percent level of confidence, and the combined data give an age of 305 $\pm$ 15 m.y. All variance can be attributed to experimental error. This age is considered to be the most reliable estimate of the Rb/Sr age of these granites, and will only be improved upon, with present techniques, if rocks with higher Rb/Sr ratios can be found.

The known Carboniferous granites in the Auburn Complex occur only along the western side of the batholith. The reasonable agreement between the K/Ar and Rb/Sr ages suggests that the rocks of the western part of the complex were not affected by the magmatic activity that occurred a few kilometres to the east in the Late Permian.

Permian-Triassic Intrusions

Plutonic activity occurred in the late Permian and early Triassic over a wide area of southern Queensland and New England. The K/Ar results presented here (Table 14) and data published by Evernden & Richards (1962), Cooper et al. (1963), and Binns & Richards (1964) spread over a period of 20 million years, between 250 and 230 m.y. ago. The scatter is much greater than the expected experimental error ($\pm$ 6 m.y.) associated with a single magmatic event.

The area of outcrop of the Upper Permian granites is divided into three arbitrarily chosen regions for the purpose of examining the spread in ages. The results from each region and New England are represented in the histograms in Figure B. The total spread in ages from 250 to 230 m.y. in each group is almost identical, and no significant differences can be found between the groups.

The recognition of statistically valid differences in the ages within any one group is difficult, due partly to the paucity of data, but mainly to the problem of defining subgroups within each group which are acceptable on geological grounds. It has been possible to do this in the Marlborough area where there is a general trend in the sequence of intrusion from gabbro (earliest) to adamellite (latest) which can be demonstrated in the field (Malone et al., 1969). When the K/Ar ages of these rocks are divided into two groups according to rock type (gabbro-diorite and granodiorite-adamellite) it is found that these groups have mean ages of 244 + 1 m.y. and 236 + 1 m.y. respectively. Application of Student's t-test to these data shows that there is a greater than 99.9 percent probability that the means are significantly different. These two groups are differentiated in the histogram in Figure B, the shaded area representing the ages determined on the more basic rocks.

In other areas a distinction of this type cannot be made on the evidence at present available. In both the Rockhampton/Auburn Complex area and in southeastern Queensland, a distinct peak occurs at 235 m.y., identical with the younger group at Marlborough, while a smaller number of determinations spread down to 250 m.y.

Rocks from the Auburn Complex which give the 250 m.y. K/Ar ages are strongly banded and recrystallized rocks (GA1370, 5343). Other metamorphic rocks in the Auburn Complex (GA5342, 5344, 5357) have K/Ar mineral ages of 235 m.y., which probably reflect the age of the granites which intrude them, for example GA5345. Thus, the 250-m.y. dates measured on samples GA1370 and GA5343 may not be a metamorphic age, but be the result of incomplete outgassing of argon during the 235-m.y. old intrusive event. The granites of Carboniferous age in the west of the complex give no indications of having suffered any dynamic or thermal metamorphism since their emplacement, so the metamorphic rocks could be even older than Carboniferous.

Two distinct plutonic episodes can therefore be recognized in the late Permian on the basis of the isotopic ages. Gabbroic and dioritic bodies were emplaced near Marlborough 245 m.y. ago, and widespread granitic activity occurred from Marlborough to New England between 235 and 230 m.y. ago. There is no definite evidence in Queensland of a phase of regional metamorphism 250 m.y. ago corresponding to that recognized in New England (Binns & Richards, 1964). If regional metamorphism occurred, it could not have been on a large scale, as the older granites of Mount Morgan and the western part of the Auburn Complex do not exhibit any marked argon leakage.

Granites dated at 220 m.y. have been reported from the South Coastal High and the Maryborough Basin (Evernden & Richards, 1962; Webb & McDougall, 1967). Other granitic rocks of this age occur to the south in the New England Batholith, and to the northwest in the Yarrol Basin (Table 15). North of Rockhampton, a dyke (near Marlborough) and two small gabbro stocks (in the Connors Arch) also have ages of approximately 220 m.y., but there is no evidence of widespread plutonism in the northern area during the Triassic.

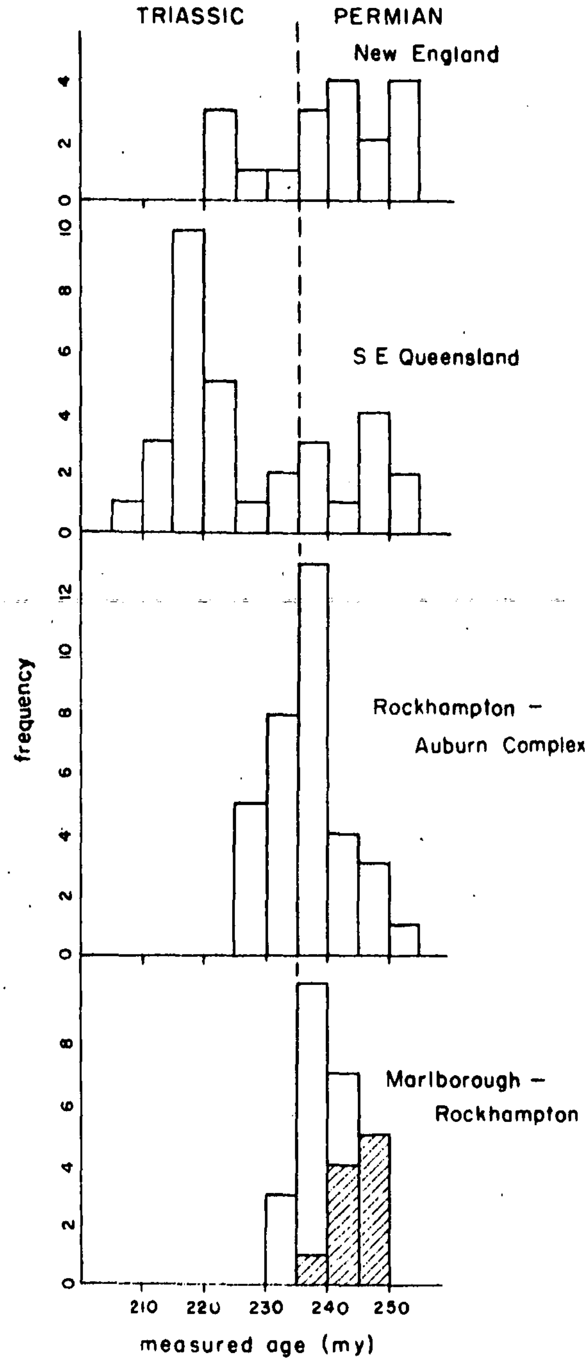
COMPARISON OF BIOTITE AND HORNBLENDE K-Ar AGES

It was stated earlier that the difference in argon retentivity between biotite and hornblende under metamorphic conditions suggested by Hart (1964) and Aldrich et al. (1965) was not always observed. In the present work, K/Ar ages have been measured on 51 pairs of cogenetic biotite and hornblende, and a histogram of the ratio biotite/hornblende age is given in Figure C. Figure C1 contains samples from the Urannah Complex which are known to have lost radiogenic argon during burial and possible thermal metamorphism. Some samples included in Figure C2 may also have lost argon, but this cannot be substantiated.

If biotite and hornblende are equally retentive of argon, the mean ratio would be 1.00, whereas in cases where hornblende is more retentive, for example, under conditions of thermal metamorphism, the mean ratio would be less than 1.00. The mean ratios in Figures C1 and C2 (0.990 and 0.998) are not significantly different, either from each other or from 1.00.

The samples represented in Figure C1 were emplaced 305 m.y. ago and were overlain, or partly overlain by the Lizzie Creek Volcanics 270 m.y. ago. Evidence of the thermal history during this 35 m.y. interval is lacking. The region was depressed during the early Permian, when a large thickness of sediments was deposited on the Lizzie Creek Volcanics. It is not known whether the Urannah Complex was buried beneath the deepest part of the basin, or whether it remained partly emergent near the margin of the basin. The Thunderbolt Granite was emplaced in the Urannah Complex 265 m.y. ago.

Jensen (1964) reported the development of prehnite, pumpellyite, and perhaps epidote in the lower sections of the Lizzie Creek Volcanics. These minerals are characteristic of the prehnite-pumpellyite metagreywacke facies (Coombs, 1961), and investigations by Coombs et al. (1959) and Packham & Crook (1960) suggest that temperatures up to 300°C may have been involved. However, this temperature seems excessive, even in a geosynclinal region for a depth of about 6000 m. A closer estimate of the temperature at the base



M(Pt) 82

Fig. B To accompany record 1971/64

A comparison in the spread of Permian and Triassic ages ....

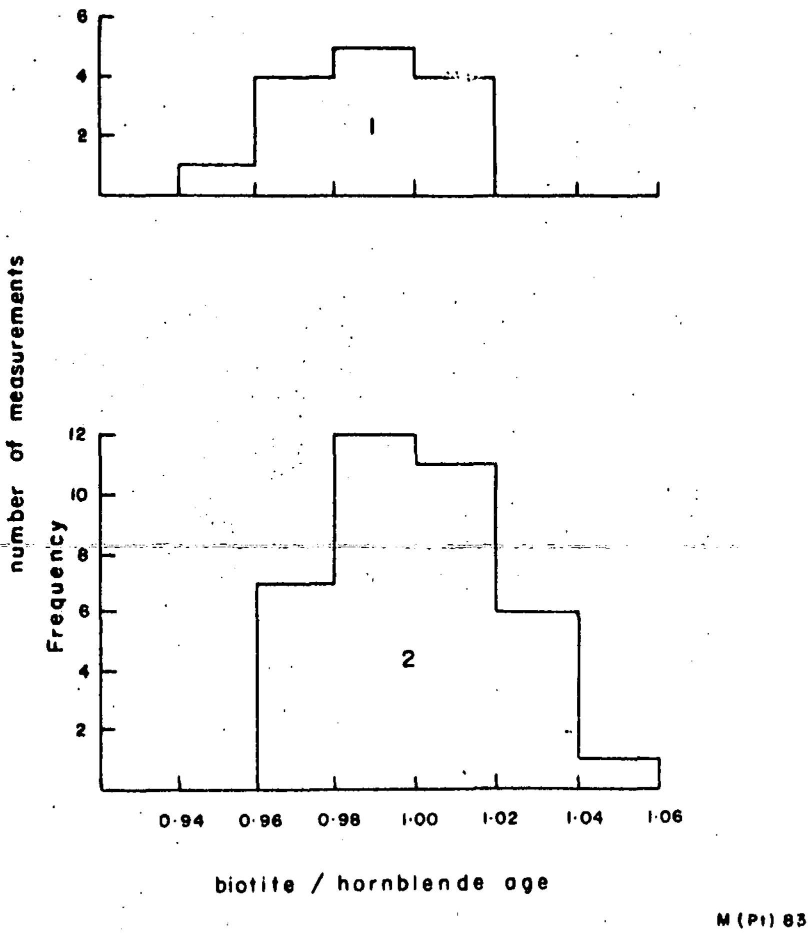


Fig. C To accompany record 1971/64

The frequency distribution of the ratio of the biotite age to the hornblende age of the Lizzie Creek Volcanics during the early Permian may be about 200°C. The absence of any schistosity in the volcanics indicates that heat and static load (burial metamorphism, Coombs, 1961) were the main factors operating at this time.

If the granites of the Urannah Complex were overlain by the thickest section of sediments and volcanics, then the temperature in the granites must have been even greater than that in the volcanics. The depth at which the present granite land surface was below the volcanics is not known, but indications of regional faulting between the granites and volcanics suggest uplift of the granites in the north. The present outcrop of the Urannah Complex also seems to indicate that the northern region has been tilted or raised relative to the southern end.

The K/Ar mineral ages on the Urannah Complex decrease from 305 m.y. in the south to 270 m.y. in the north and were interpreted as indicating variable argon leakage from biotite and hornblende from rocks that were all 305 m.y. old. If the K/Ar ages can be related to depth of burial (and therefore to temperature), then the dating supports the assumption of differential uplift from south to north.

The maximum temperature reached in the granites may have been between 200° and 300°C, and could not have continued for more than about 5 million years (the 265 m.y. age of the Thunderbolt Granite indicates that the temperature had fallen by that time, either due to lowering of the isotherms or uplift of the granites).

Damon (1967) calculated from the data produced by Evernden et al. (1960) and Hart (1964) that low-grade metamorphism (100° to 150°C) for 50 m.y. would cause a loss of between 10 and 90 percent of argon from biotite, but less than 10 percent from hornblende. At 230°C, biotite would lose all of its radiogenic argon in less than 1 m.y., but hornblende would lose only about 10 percent in 50 m.y. A temperature of around 400°C would be needed to outgas hornblende completely in 5 m.y.

The estimated maximum temperature reached in the Urannah Complex (about 300°C) for 5 m.y. could easily account for the 270 m.y. ages of the biotites, but the predicted argon loss from hornblende for this time and temperature appears to be underestimated. Hence, under certain low-grade metamorphic conditions, the argon retentivity of hornblende may not be significantly greater than that of biotite. The concordance of biotite and hornblende K/Ar dates could lead to the erroneous conclusion that the date is the time of emplacement or of strong metamorphism. In the present case, the K/Ar age of 270 m.y. could be accepted as the age of intrusion since there is no field evidence to the contrary, and it is the Rb/Sr total rock age that indicates the leakage of argon from these rocks.

This illustrates the care that must be exercised in the interpretation of K/Ar ages, but also shows the details of geological history that can be detected when the K/Ar method is used in conjunction with the Rb/Sr method. Although the Rb/Sr method would have led to a more correct, but still incomplete conclusion, the greater sensitivity of argon diffusion to geological events has revealed the finer detail of the geological history.

REFERENCES

ALDRICH, L.T., DAVIS, G.L., and JAMES, H.L., 1965 - Ages of minerals from metamorphic and igneous rocks near Iron Mountain, Michigan. J. Pet., 6, 445-72.

ALDRICH, L.T., and WETHERILL, G.W., 1958 - Geochronology by radioactive decay. Ann. Rev. Nucl. Sci., 8, 257-98.

ARRIENS, P.A., BROOKS, C., COMPSTON, W., and BOFINGER, V.M., 1966 - The discordance of mineral ages in granitic rocks resulting from the redistribution of rubidium and strontium. J. geophys. Res., 71, 4981-94.

BINNS, R.A., and RICHARDS, J.R., 1964 - Regional metamorphic rocks of Permian age from the New England district of New South Wales. Aust. J. Sci., 27, 233.

CAREY, S.W., and BROWNE, W.R., 1938 - Review of the Carboniferous stratigraphy, tectonics and palaeogeography of New South Wales and Queensland. J. Roy. Soc. N.S.W., 71, 591-614.

CASEY, R., 1964 - The Cretaceous Period; in The Phanerozoic Time Scale. Quart. J. geol. Soc. Lond. (Supplement), 120S, 193-202.

CLARKE, D.E., PAINE, A.G.L., and JENSEN, A.R., 1971 - Geology of the Proserpine 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rep. 144.

COMPSTON, W., and JEFFERY, P.M., 1959 - Anomalous common strontium in granite. Nature, 184, 1792-3.

COMPSTON, W., LOVERING, J.F., and VERNON, M.J., 1965 - The rubidium-strontium age of the Bishopville aubrite and its component enstatite and feldspar. Geochim. Cosmochim. Acta, 29, 1085-99.

COOPER, J.A., 1963 - The flame photometric determination of potassium in geological materials used for potassium-argon dating. Geochim. Cosmochim. Acta, 27, 525-46.

COOPER, J.A., RICHARDS, J.R., and WEBB, A.W., 1963 - Some potassium-argon ages in New England, New South Wales. J. geol. Soc. Aust., 10, 313-6.

COOPER, J.A., MARTIN, I.D., and VERNON, M.J., 1966 - Evaluation of rubidium and iron bias in flame photometric potassium determination for K-Ar dating. Geochim. Cosmochim. Acta, 30, 197-205.

COOMBS, D.S., 1961 - Some recent work on the lower grades of metamorphism. Aust. J. Sci., 24, 203-15.

COOMBS, D.S., ELLIS, A.J., FYFE, W.A., and TAYLOR, A.M., 1959 - The zeolite facies, with comments on the interpretation of hydrothermal syntheses. Geochim. Cosmochim. Acta, 17, 53-107.

DAMON, P.E., 1967 - Potassium-argon dating of igneous and metamorphic rocks with applications to the Basin Ranges of Arizona and Sonora; in RADIOMETRIC DATING FOR GEOLOGISTS, eds E.I. Hamilton and R.M. Farquhar. London, Interscience.

DEAR, J.F., McKELLAR, R.G., and TUCKER, R.M., in prep. - The geology of the Monto 1:250,000 Sheet area, Queensland. Geol. Surv. Qld Rep.

DENMEAD, A.K., 1931 - New gold discovery on Cracow Holding. Qld Govt Min. J., 32, 307-8.

DENMEAD, A.K., 1945 - Kilkivan mercury deposits. Ibid., 46, 13-22.

DENMEAD, A.K., 1946 - Notes on Cracow goldfield. Ibid., 47, 306-11.

DICKINS, J.M., MALONE, E.J., and JENSEN, A.R., 1964 - Subdivision and correlation of the Permian Middle Bowen Beds. Bur. Miner. Resour. Aust. Rep. 70.

EVERNDEN, J.F., CURTIS, G.H., KISTLER, R.W., and OBRADOVICH, J., 1960 - Argon diffusion in glauconite, microcline, sanidine, leucite and phlogopite. Amer. J. Sci., 258, 583-604.

EVERNDEN, J.F., and RICHARDS, J.R., 1962 - Potassium-argon ages in eastern Australia. J. geol. Soc. Aust., 9, 1-50.

FLYNN, K.F., and GLENDENIN, L.E., 1959 - The half-line and beta spectrum of ^{87}Rb. Phys. Rev., 116, 744-8.

FRANCIS, S.H., and WOODLAND, A.W., 1964 - The Carboniferous Period; in the Phanerozoic Time Scale. Quart J. geol. Soc. Lond. (Supplement), 120S, 221-32.

HANSON, G.N., and GAST, P.W., 1967 - Kinetic studies in contact metamorphic zones. Geochim. Cosmochim. Acta, 31, 1119-53.

HART, S.R., 1964 - The petrography and isotopic mineral age relations of a contact zone in the Front Range, Colorado. J. Geol., 72, 493-525.

HURLEY, P.M., HUGHES, H., PINSON, W.H., and FAIRBAIRN, H.W., 1962 - Radiogenic argon and strontium diffusion parameters in biotite at low temperatures obtained from Alpine Fault uplift in New Zealand. Geochim. Cosmochim. Acta, 26, 67-80.

JENSEN, A.R., 1964 - The geology of the Blenheim area. M.Sc. thesis, Aust. Nat. Uni. (unpubl.).

KIRKEGAARD, A.G., SHAW, R.D., and MURRAY, C.G., in prep. - The geology of the Rockhampton and Port Clinton 1:250,000 Sheet areas, Queensland. Geol. Surv. Qld Rep.

McDOUGALL, I., 1966 - Precision methods of potassium-argon isotopic age determinations on young rocks; in METHODS AND TECHNIQUES IN GEOPHYSICS, 2. London, Interscience.

McDOUGALL, I., COMPSTON, W., and BOFINGER, V.M., 1966 - Isotopic age determinations on Upper Devonian rocks from Victoria, Australia: a revised estimate for the age of the Devonian-Carboniferous boundary. Bull. geol. Soc. Amer., 77, 1075-88.

McINTYRE, G.A., BROOKS, C., COMPSTON, W., and TUREK, A., 1966 - The statistical assessment of Rb-Sr isochrons. J. geophys. Res., 71, 5459-68.

MALONE, E.J., JENSEN, A.R., and GREGORY, C.M., 1966 - Geology of the southern half of the Bowen 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rep. 100.

MALONE, E.J., OLGERS, F., and KIRKEGAARD, A.G., 1969 - The geology of the Duaringa and Saint Lawrence 1:250,000 Sheet areas, Queensland. Ibid., 121.

NICOLAYSEN, L.O., 1961 - Graphic interpretation of discordant age measurements on metamorphic rocks. Ann. N.Y. Acad. Sci., 91(2), 198-206.

NIER, A.O., 1938 - Isotopic composition of Sr, Ba, Bi, Ti and Hg. Phys. Rev., 54, 275-8.

NIER, A.O., 1950 - A redetermination of the relative abundances of the isotopes of carbon, nitrogen, oxygen, argon and potassium. Ibid., 77, 789-93.

PACKHAM, G.H., and CROOK, K.A.W., 1960 - The principle of diagenetic facies and some of its implications. J. Geol., 68, 392-407.

PAINE, A.G.L., CLARKE, D.E., and GREGORY, C.M., in prep. - The geology of the northern half of the Bowen 1:250,000 Sheet area, Queensland (with additions to the geology of the southern half). Bur. Miner. Resour. Aust. Rep.

REID, J.H., 1930 - The Queensland Upper Palaeozoic succession. Geol. Surv. Qld Publ. 278, 1-96.

RICHARDS, J.R., WHITE, D.A., WEBB, A.W., and BRANCH, C.D., 1966 - Isotopic ages of acid igneous rocks in the Cairns hinterland, north Queensland. Bur. Miner. Resour. Aust. Bull. 88.

SHIELDS, W.R., and GARNER, E.L., 1963 - Survey of Rb^{85}/Rb^{87} in minerals. J. geophys. Res., 68, 2331-4.

SMITH, D.B., 1964 - The Permian Period; in The Phanerozoic Time Scale. Quart. J. geol. Soc. Lond. (Supplement), 120S, 211-20.

VEEVERS, J.J., MOLLAN, R.G., OLGERS, F., and KIRKEGAARD, A.G., 1964 - The geology of the Emerald 1:250,000 Sheet area, Queensland. Bur. Miner. Resour. Aust. Rep. 68.

WEBB, A.W., COOPER, J.A., and RICHARDS, J.R., 1963 - Potassium-argon ages on some central Queensland granites. J. geol. Soc. Aust., 10, 317-24.

WEBB, A.W., and McDOUGALL, I., 1964 - Granites of Lower Cretaceous age near Eungella, Queensland. Ibid., 11, 151-3.

WEBB, A.W., and McDOUGALL, I., 1967 - Isotopic dating evidence on the age of the Upper Permian and Middle Triassic. Earth plan. Sci. Lett., 2, 483-8.

WHITE, W.C., and BROWN, G.A., 1963 - Preliminary report on the geology of the Mackay region, area 93P and southern part of 94P. Geol. Surv. Qld Auth. Rep. 1033 (unpubl.).

APPENDIX

Rock Type and Sample Localities

The samples listed each have two numbers. The GA number is the official registration of the sample in the Department of Geophysics and Geochemistry, ANU. The other number contains the reference to a 1:250,000 Sheet area and the sample identification for the Sheet in the BMR collection, e.g. F55/15/1 is sample number 1 collected from the F55/15 Sheet. The grid reference is taken from the military grid for the particular 1:250,000 Sheet.

GA399; F55/15/1: Retreat Granite; 581200, 2113300; Table 1.

GA400; F55/15/2: Retreat Granite; 581000, 2105500; Table 1.

GA401; F55/15/3: Retreat Granite; 591200, 2065900; Table 1.

GA402; F55/15/4: Retreat Granite; 585500, 2097300; Table 1.

GA472; F55/3/12: Urannah Complex; 661000, 385000; Tables 5, 6.

GA473; F55/3/14: Urannah Complex; 620000, 445000; Table 8A.

GA474; F55/3/15: Urannah Complex; 627000, 455000; Table 5.

GA729; F55/3/3: Adamellite; 569400, 241120; Tables 2, 4.

GA812; F55/3/13: Urannah Complex; 647500, 2409300; Tables 5, 6.

GA831; F55/3/8: Granodiorite; 536500, 2415600; Tables 2, 4.

GA832; F55/3/1: Adamellite; 552700, 2441800; Tables 2, 4.

GA887; G56/1/14: Granodiorite; Mulgildie 1 well, core 14, 3992'-3993'; lat 24°58'S, long 151°08'E; Table 14.

GA1024; F55/15/9: Retreat Granite; 569600, 2079600; Table 1.

GA1025; F55/15/11: Retreat Granite; 576000, 2129300; Table 1.

GA1026; F55/15/12: Retreat Granite; 556700, 211500; Table 1.

GA1027; F55/15/13: Retreat Granite; 562000, 2118000; Table 1.

GA1028; F55/15/8: Retreat Granite; 573300, 2073000; Table 1.

GA1029; F55/15/14: Adamellite; 571000, 2070500; Table 2.

GA1030; F55/15/15: Adamellite; 570000, 2069400; Table 2.

GA1040; F55/11/2: Anakie Metamorphics; lat 22°51'S, long 147°28'E; Table 1.

GA1053; F55/12/10: Xenolithic granodiorites: A, matrix; B, xenolith; 273600, 2149500; Table 14.

GA1054; F55/12/12: Granodiorite; 275500, 2167000; Table 14.
GA1067; G56/5/5: Auburn Complex; 337400, 1863900; Tables 5, 6.
GA1068; F55/16/2: Diorite; 267700, 2077400; Table 14.
GA1069; F55/16/3: Adamellite; 269300, 2075500; Table 14.
GA1072; F55/3/11: Urannah Complex; 662700, 2393300; Tables 5, 6.
GA1073; F55/7/1: Adamellite; 581800, 2347800; Table 2.
GA1136; F55/8/9: Urannah Complex; 241300, 2347600; Table 5.
GA1137; F55/8/10: Urannah Complex; 138000, 2346600; Table 5.
GA1138; F55/8/11: Urannah Complex; 136600, 2342000; Table 5.
GA1142; F55/4/2: Granite; 171000, 2384400; Table 10.
GA1154; F55/4/3: Granite; 171000, 2385300; Table 10.
GA1155; F55/12/4: Gabbro; 193000, 2228000; Table 15.
GA1160; F55/3/17: Adamellite; 536900, 2387000; Tables 2, 4.
GA1161; F55/3/18: Adamellite; 532800, 2387100; Table 2.
GA1162; F55/3/24: Urannah Complex; 625000, 2423900; Table 5.
GA1163; F55/12/11: Diorite; 275200, 2166100; Table 14.
GA1164; F55/12/13: Diorite; 275500, 2167900; Table 14.
GA1166; G56/1/1: Granodiorite; 372000, 1988800; Table 14.
GA1167; G56/1/2: Granodiorite; 370300, 1995200; Table 14.
GA1168; G56/5/2: Auburn Complex; 352500, 1849100; Table 14.
GA1169; G56/5/3: Auburn Complex; 350700, 1846700; Table 14.
GA1170; F55/4/5: Urannah Complex; 121600, 2398000; Table 10.
GA1187; F55/12/1: Gabbro; 209500, 2222200; Table 15.
GA1189; F55/12/9: Urannah Complex; 218100, 2190200; Table 5.
GA1190; G56/5/7: Auburn Complex; 310300, 1874000; Tables 5, 6.
GA1243; F55/3/20: Granodiorite; 532500, 2400000; Tables 2, 4.
GA1244; F55/11/5: Micrgranodiorite; 664500, 2243600; Table 10.
GA1245; G56/1/3: Granodiorite; 412500, 1978200; Table 15.
GA1246; G56/1/5: Granodiorite; 431900, 1961100; Table 15.
GA1247; G56/1/6: Granodiorite; 431900, 1942700; Table 15.
GA1248; G56/1/7: Granodiorite; 428400, 1942700; Table 15.

GA1249; G56/1/8: Granodiorite; Auburn Complex; 369000, 1923400; Table 14.

GA1250; G56/1/10: Granodiorite; 380400, 1903600; Table 14.

GA1251; G56/1/12: Granodiorite, Auburn Complex; 341900, 1908400; Table 5.

GA1369; G56/1/9: Granodiorite, Auburn Complex; 383900, 1919000; Table 14.

GA1370; G56/1/11: Granodiorite, Auburn Complex; 355300, 1899400; Table 14.

GA5198; F55/3/23: Granodiorite; 574900, 2423500; Table 2.

GA5252; F55/3/26: Adamellite, Thunderbolt Granite; 619700, 2457000; Tables 8 A, B.

GA5253; F55/3/27: Granodiorite, Thunderbolt Granite; 614300, 2446800; Table 8A.

GA5256; F55/12/14: Granodiorite; 274200, 2149000; Table 14.

GA5257; F55/12/15: Gabbro; 273300, 2147800; Table 14.

GA5258; F56/9/1: Pegmatite; 289400, 2156500; Table 16.

GA5259; F56/9/2: Gabbro; 289700, 2157900; Table 14.

GA5261; F56/9/4: Granodiorite; 290600, 2162100; Table 14.

GA5263; F55/12/16: Hornblende gabbro; 278900, 2168000; Table 14.

GA5264; F55/12/17: Diorite; 275200, 2168000; Table 14.

GA5265; F55/12/18: Granodiorite; 275500, 2166700; Table 14.

GA5266; F55/12/19: Diorite; 275500, 2166400; Table 14.

GA5267; F55/8/12: Granodiorite, Urannah Complex; 147900, 2333500; Table 5.

GA5269; F55/12/20: Granodiorite; 220500, 2162000; Table 6.

GA5270; F55/12/21: Granodiorite; 219500, 2190500; Table 6.

GA5272; F55/3/33: Gabbro; 636700, 2373900; Table 10.

GA5289; F55/12/3: Granodiorite, Urannah Complex; 207300, 2234000; Tables 5, 6.

GA5290; F55/12/8: Granodiorite, Urannah Complex; 217500, 2189600; Table 5.

GA5291; F55/8/8: Granodiorite, Urannah Complex; 207000, 2294100; Table 5.

GA5292; F55/3/9: Granodiorite; 528700, 2402900; Table 2.

GA5293; F55/7/8: Granodiorite, Urannah Complex; 683100, 2346300; Table 5.

GA5294; G56/5/4: Granodiorite, Auburn Complex; 336300, 1860600; Table 5.

GA5327; F55/3/105: Diorite, Urannah Complex; 631150, 2443750; Table 5.

GA5328; F55/3/104: Diorite, Urannah Complex; 626800, 2446300; Table 5.

GA5329; F55/3/107: Microdiorite dyke; 65400, 2423100; Table 9.

GA5330; F55/3/62: Granodiorite; 669800, 2440950; Table 10.

GA5331; F55/3/61: Adamellite; 665100, 2434500; Table 10.

GA5332; F55/3/86: Adamellite; 615700, 2458100; Tables 8 A, B.

GA5333; F55/3/101: Diorite, Urannah Complex; 622900, 2462200; Table 5.

GA5335; F55/3/37: Granodiorite, Urannah Complex; 643000, 2410900; Table 5.

GA5336; F55/3/87: Diorite, Urannah Complex; 612700, 2458300; Table 5.

GA5337; G56/5/21: Granite; 413500, 1845600; Table 14.

GA5338; F55/3/38: Adamellite; 629290, 2437450; Table 8A.

GA5339; F56/13/10: Tonalite; 330000, 2056400; Table 1.

GA5340; F56/13/11: Feldspar porphyry dyke; 330300, 2055700; Table 14.

GA5341; F56/13/13: Granodiorite; 332000, 2062600; Table 14.

GA5342; G56/5/10: Amphibolite; 375400, 1843300; Table 14.

GA5343; G56/1/17: Banded adamellite; 354200, 1894700; Table 14.

GA5344; G56/5/12: Biotite gneiss, Auburn Complex; 378800, 1841900; Table 14.

GA5345; G56/5/13: Adamellite, Auburn Complex; 379000, 1841900; Table 14.

GA5346; F55/3/113: Diorite, Urannah Complex; 683100, 2397300; Table 5.

GA5347; F55/3/106: Adamellite; 656100, 2424700; Table 5.

GA5348; G56/1/15: Granodiorite; 379000, 1926000; Table 14.

GA5350; G56/5/14: Granodiorite, Auburn Complex; 385400, 1840200; Table 14.

GA5351; G56/5/16: Diorite; 410700, 1846000; Table 14.

GA5352; G56/5/18: Granodiorite, Auburn Complex; 383300, 1874800; Table 14.

GA5353; G56/5/19: Granodiorite, Auburn Complex; 384500, 1885700; Table 14.

GA5354; F55/3/135: Adamellite, Urannah Complex; 6845000, 2408500; Tables 5, 6.

GA5355; F55/3/117: Adamellite; 6443500, 2458500; Table 10.

GA5356; F55/3/118: Adamellite; 648000, 2445500; Table 10.

GA5357; G56/5/11: Biotite gneiss, Auburn Complex; 376600, 1842400; Table 14.

GA5358; F55/3/127: Adamellite; 624100, 2411700; Table 10.

GA5359; F56/9/6: Granodiorite; 359100, 2157300; Table 14.

GA5360; F56/13/5: Diorite; 341000, 2087300; Table 14.

GA5361; G56/1/21: Granodiorite, Auburn Complex; 340500, 1904600; Tables 5, 6.

GA5362; G56/5/15: Adamellite, Auburn Complex; 390800, 1838600; Table 14.

GA5364; G56/5/20: Granodiorite, Auburn Complex; 396700, 1876700; Table 14.

GA5365; F55/3/125: Adamellite; 662600, 2398700; Table 9A.

GA5369; F56/13/15: Diorite; 332400, 2057400; Table 1.

GA5370; F56/13/16: Diorite; 328700, 2054600; Table 1.

GA5371; F56/13/17: Diorite; 329700, 2053200; Table 1.

GA5372; F56/13/18: Diorite; 333100, 2053900; Table 1.

GA5373; F55/3/55: Basalt; 565800, 2455500; Table 11.

GA5374; F55/3/56: Basalt; 568860, 2452500; Table 11.

GA5375; F55/3/68: Basalt; 566700, 2475000; Table 11.

GA5378; F55/3/36: Granodiorite; 630350, 2423600; Table 8A.

GA5379; F55/3/108: Gneissic granite, Urannah Complex; 647800, 2413700; Table 5.

GA5380; F55/3/109: Adamellite; 630300, 2432800; Table 8A.

GA5391; F55/3/42: Adamellite; 546900, 2440500; Tables 2, 4.

GA5392; F55/3/115: Granodiorite, Urannah Complex; 681100, 2399000; Tables 5, 6.

GA5393; F56/13/6: Adamellite; 318000, 2064900; Table 14.

GA5394; F55/4/9: Porphyry; 175100, 2447100; Table 10.

GA5396; F55/3/114: Adamellite, Urannah Complex; 679800, 2401700; Tables 5, 6.

GA5397; F55/8/14: Adamellite, Urannah Complex; 116400, 2372900; Table 5.

GA5398; F55/3/91: Adamellite; 641250, 2444200; Table 10.

GA5399; F55/3/100: Granodiorite; 629100, 2466400; Table 10.

GA5502; F55/7/9A: Porphyry; 674100, 2374000; Table 9A.

GA5503; F55/7/9B: Porphyry; 674100, 2374000; Table 9A.

GA5504; F55/7/9C: Porphyry; 674100, 2374000; Table 9A.

GA5505; F55/7/9D: Porphyry; 674100, 2374000; Table 9A.

GA5506; F55/7/9E: Porphyry; 674100, 2374000; Table 9A.

GA5507; F55/4/23: Proserpine Volcanics; 139500, 2447800; Table 13.

GA5508; F55/4/20: Proserpine Volcanics; 143800, 2447900; Table 13.

GA5511; F55/4/22: Proserpine Volcanics; 138900, 2445100; Table 13.

GA5512; F55/4/21: Proserpine Volcanics; 137800, 2445200; Table 13.

GA5514; F55/3/40: Bulgonunna Volcanics; 546950, 2438900; Table 3.

GA5515; F55/3/41: Bulgonunna Volcanics; 546950, 2438850; Table 3.

GA5517; F55/3/71: Bulgonunna Volcanics; 564000, 2408200; Table 3.

GA5518; F55/3/84: Bulgonunna Volcanics; 561700, 2407500; Table 3.

GA5519; F55/3/143: Acid dyke; 569300, 2436200; Table 12.

GA5520; F55/3/69: Acid volcanics; 562050, 2475700; Table 12.

GA5521; F55/3/74: Acid volcanics; 565100, 2448600; Table 12.

GA5522; F55/3/75: Acid volcanic; 565100, 2448700; Table 12.

GA5523; F55/3/76: Acid volcanic; 564800, 2448500; Table 12.

GA5524; F55/3/72: Acid volcanic; 572700, 2455600; Table 12.

GA5525; F55/3/78: Acid volcanic; 577200, 2443700; Table 12.

GA5528; F55/3/22: Granite; 567200, 2411300; Table 4.

GA5531; F55/3/119: Granite; 600600, 2480200; Table 10.

GA5532; F55/3/16: Adamellite; 575200, 2417300; Table 12.

GA5534; F55/3/94: 656100, 3475100; Table 5.

GA5539; F45/4/33: Proserpine Volcanics; 136600, 2444100; Table 13.

GA5546; F55/4/26: Proserpine Volcanics; 137400, 244550; Table 13.

GA5547; F55/4/27: Proserpine Volcanics; 139200, 2445200; Table 13.

GA5552; F55/4/32: Proserpine Volcanics; 136400, 2442200; Table 13.

GA5553; F55/4/25: Dacite; 205800, 2399800; Table 10.

GA5554; F56/1/20: Granodiorite, Auburn Complex; 328200, 1947200; Table 6.

GA5555; G56/1/22: Granodiorite, Auburn Complex; 321000, 1898100; Table 6.

GA5556; F55/3/131: Bulgonunna Volcanics; 538700, 2394300; Table 3.

GA5557; F55/3/132: Bulgonunna Volcanics; 555900, 2389700; Table 3.

GA5559; F55/3/134: Bulgonunna Volcanics; 573400, 2429700; Table 3.

GA5560; F55/3/136: Adamellite; 655900, 2427800; Table 5.

TABLE 1. K/Ar AGES OF PRE-DEVONIAN AND DEVONIAN ROCKS

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^*/^{40}K$	Ar Atm (%)	Age (m.y.)
RETREAT GRANITE						
399	Biotite	7.104 7.074	7.09	(1)0.02265 (2)0.02284	7.5 2.4	353 355
400	Biotite	7.118 7.088	7.10	0.02212	6.0	345
"	Hornblende	0.7266 0.7251	0.726	0.02304	10.8	358
401	Biotite	7.269 7.285	7.28	0.02357	3.6	366
"	Hornblende	0.7348 0.7323	0.734	0.02366	11.5	367
402	Biotite	6.708 6.731	6.72	0.02238	5.5	349
"	Hornblende	0.5735 0.5777	0.576	0.02290	14.9	356
1024	Biotite	7.169 7.152	7.16	0.02339	2.4	363
1025	Biotite	6.284 6.305	6.29	0.02403	3.2	372
1026	Biotite	7.279 7.227	7.25	0.02361	10.4	366
1027	Biotite	6.331 6.339	6.34	0.02337	1.5	363
"	Hornblende	0.6396 0.6358	0.638	0.02273	6.9	354
1028	Biotite	6.737 6.743	6.74	0.02343	2.2	364
MT MORGAN TONALITE						
5339	Hornblende	0.2920 0.2905	0.291	0.02316	23.0	360
5369	Hornblende	0.3899 0.3872	0.389	0.02295	21.7	357

Table 1 (cont.)

GA No	Mineral	K (%)	Av.K (%)	$^{40}Ar^*/^{40}K$	Ar Atm (%)	Age (m.y.)
5370	Hornblende	0.3585 0.3608	0.360	0.02351	31.1	365
5371	Hornblende	0.4146 0.4156	0.415	0.02387	34.6	370
5372	Hornblende	0.0968 0.0964	0.0966	0.02306	60.5	358
ANAKIE METAMORPHICS						
1040	Muscovite	7.835 7.822	7.83	0.03028	1.7	458

TABLE 2. K/Ar AGES OF CARBONIFEROUS GRANITES IN THE ANAKIE HIGH INLIER

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^*/^{40}K$	Ar Atm (%)	Age (m.y.)
DEVONIAN-CARBONIFEROUS GRANITES						
1160	Biotite	7.481 7.491	7.49	0.01859	2.0	294
"	Hornblende	0.3882 0.3859	0.387	0.01859	9.1	294
1161	Biotite	7.545 7.566	7.56	0.01834	2.3	290
5288	Hornblende	0.4052 0.4102 0.4081	0.408	(1)0.02085 (2)0.02110	10.0 50.4	327 330
GRANITES INTRUDING BULGONUNNA VOLCANICS						
729	Biotite	5.784 5.797	5.79	(1)0.01803 (2)0.01786	12.0 7.8	286 283
831	Biotite	6.252 6.287	6.27	(1)0.01737 (2)0.01819 (3)0.01850 (4)0.01781	3.2 2.7 2.5 8.0	276 288 293 283

TABLE 2 (cont.)

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^{*}/^{40}K$	Ar Atm (%)	Age (m.y.)
832	Biotite	5.668	5.65	(1)0.01752	6.3	278
		5.624		(2)0.01768	4.4	281
1073	Hornblende	0.4921	0.492			
		0.4920		0.01799	11.0	285
1243	Biotite	6.322	6.33	0.01764	2.1	280
		6.343				
"	Hornblende	0.3236	0.326	0.01762	22.5	280
		0.3277				
5198	Biotite	5.647	5.65	(1)0.01783	2.0	283
		5.652		(2)0.01824	25.6	289
				(3)0.01746	2.5	278
"	Hornblende	0.4605	0.462	(1)0.01837	26.0	291
		0.4631		(2)0.01779	10.1	282
5292	Hornblende	0.2341	0.234	(1)0.01768	18.1	281
		0.2333		(2)0.01784	24.2	283
5391	Biotite	6.588	6.59	0.01776	7.5	282
		6.596				
OTHER INTRUSIONS						
1029	Biotite	6.896	6.90	(1)0.01773	6.9	281
		6.898		(2)0.01883	2.6	298
"	Hornblende	0.5848	0.583	(1)0.01788	14.9	286
		0.5811		(2)0.01834	15.0	290
1030	Biotite	6.038	6.05	(1)0.01897	10.4	300
		6.063		(2)0.01881	2.4	297
				(3)0.01811	5.1	287
				(4)0.01860	1.8	294
"	Hornblende	0.5699	0.571	(1)0.01812	14.2	287
		0.5720		(2)0.01792	18.5	284

TABLE 3. Rb/Sr DATA FOR BULGONUNNA VOLCANICS

GA No	Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr^{+}$
5514	Total rock	118.1	221.3	1.536	0.7105	0.7112
		116.8	218.5	1.542	0.7112	
5515	Total rock	174.1	94.0	5.340	0.7272	0.7280
		174.3	93.1	5.399		0.7274
5517	Total rock	99.0	364.3	0.782	0.7088	
		97.9	363.4	0.778	0.7082	
5518	Total rock	129.8	227.2	1.648	0.7117	0.7118
5556	Total rock	152.5	267.5	1.644	0.7119	
5557	Total rock	87.0	400.0	0.628	0.7080	
5559	Total rock	164.3	108.3	4.375	0.7232	

TABLE 4. Rb/Sr DATA FOR GRANITES INTRUDING BULGONUNNA VOLCANICS

GA No	Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr^{+}$	Age (m.y.)
729	Total rock	131.9	214.9	1.773	0.7117	0.7131	
729	Biotite	377.1	20.5	53.109	0.9285		286
831	Total rock	121.8	231.6	1.519	0.7108	0.7110	
832	Total rock	161.7	152.4	3.067	0.7192	0.7181	
1160	Total rock	138.0	263.5	1.511	0.7118		
1243	Total rock	84.5	359.9	0.678	0.7076	0.7074	
5391	Total rock	214.4	158.2	3.917	0.7212	0.7216	
5391	Biotite	1082.0	14.5	214.858	1.6106		286
5528	Total rock	139.5	219.4	1.836	0.7123	0.7121	

+ Denotes measured ratio

TABLE 5. K/Ar AGES OF CARBONIFEROUS GRANITES, FROM THE URANNAH AND AUBURN COMPLEXES

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^{*}/^{40}K$	Ar Atm (%)	Age (m.y.)
AUBURN COMPLEX						
1067	Biotite	7.161 7.169	7.17	0.01906	1.8	301
1190	Biotite	6.116 6.106	6.11	0.01920	2.9	303
1251	Biotite	5.229 5.250	5.24	0.01897	1.8	300
"	Hornblende	0.4364 0.4391	0.438	0.01884	9.4	298
5294	Hornblende	0.4094 0.4072	0.408	0.01859	10.8	294
5361	Biotite	6.247 6.226	6.24	0.01895	3.8	299
URANNAH COMPLEX						
472	Biotite	7.138 7.136	7.14	(1)0.01746 (2)0.01702	5.7 4.2	277 271
(A)	Hornblende	1.4405 1.4025	1.42	0.01700	11.5	271
(B)	Hornblende	0.4422 0.4431	0.443	0.01671	30.6	266
474	Biotite	7.266 7.281	7.27	(1)0.01706 (2)0.01713	66.3 2.2	271 272
(A)	Hornblende	0.7894 0.7923 0.7880	0.789	0.01613	16.9	258
(B)	Hornblende	0.6474 0.6461	0.647	0.01613	8.0	258
812	Biotite	6.935 6.928	6.93	0.01690	6.3	270
1072	Muscovite	8.273 8.317	8.30	(1)0.01702 (2)0.01770 (3)0.01682	2.4 1.7 3.4	271 281 268

Table 5 (cont.)

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^{*}/^{40}K$	Ar Atm (%)	Age (m.y.)
1135	Biotite	7.445 7.419	7.43	0.01461	2.8	235
"	Hornblende	0.7103 0.7051	0.708	0.01464	7.9	235
1136	Biotite	7.245 7.210	7.23	(1)0.01756 (2)0.01721	2.1 1.2	279 274
1137	Biotite	6.711 6.672	6.69	0.01712	1.8	272
"	Hornblende	0.3795 0.3834	0.381	0.01674	10.2	267
1138	Biotite	6.492 6.457	6.52	0.01706	1.7	271
"	Hornblende	0.3462 0.3480	0.347	0.01750	13.2	278
1162	Biotite	6.937 6.984	6.96	0.01682	2.6	268
"	Hornblende	0.7913 0.7914	0.791	0.01719	6.2	273
1189	Biotite	5.213 5.203	5.21	0.01950	3.4	307
"	Hornblende	0.4926 0.4737 0.4792	0.482	0.02000	12.4	315
5267	Biotite	7.606 7.608	7.61	(1)0.01768 (2)0.01759	3.4 2.8	281 279
"	Hornblende	0.6224 0.6256	0.624	0.01825	10.4	289
5269	Hornblende	0.4737 0.4746	0.474	0.01913	8.8	302
5290	Hornblende	0.4678 0.4659	0.467	0.01931	8.1	305
5291	Hornblende	0.4959 0.4965	0.496	0.01816	11.8	289
5293	Hornblende	0.4585 0.4559	0.457	0.01802	10.5	286

Table 5 (cont.)

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^*/^{40}K$	Ar Atm (%)	Age (m.y.)
5327	Biotite	7.880 7.883	7.88	0.01647	2.8	263
"	Hornblende	0.3854 0.3845	0.385	0.01759	11.6	279
5328	Biotite	7.516 7.504	7.51	0.01663	3.7	265
"	Hornblende	0.5790 0.5766	0.578	0.01671	6.9	266
5333	Hornblende	0.9921 0.9969	0.995	0.01698	56.8	270
5335	Biotite	7.599 7.622	7.61	0.01686	2.4	268
"	Hornblende	0.5829 0.5790	0.581	0.01716	14.7	273
5336	Biotite	7.909 7.913	7.91	0.01666	3.6	266
"	Hornblende	1.0624 1.0600	1.061	0.01716	5.8	273
5346	Biotite	7.744 7.736	7.74	0.01786	6.2	283
5347	Biotite	7.552 7.525	7.54	(1)0.01146 (2)0.01154	3.7 9.3	187 188
5354	Biotite	7.722 7.682	7.70	0.01775	4.1	282
5379	Biotite	7.721 7.767	7.74	0.01697	4.7	270
5392	Biotite	7.303 7.332	7.32	0.01827	1.7	289
"	Hornblende	0.7406 0.7463	0.743	0.01857	28.9	294
5396	Biotite	7.467 7.462	7.46	0.01826	1.7	289
5397	Biotite	7.104 7.080	7.09	0.01683	19.0	268

Table 5 (cont.)

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar*/^{40}K$	Ar Atm (%)	Age (m.y.)
5513	Biotite	8.033 8.030	8.03	(1)0.01710 (2)0.01690	2.6 7.3	272 269
5530	Biotite	7.334 7.312	7.32	0.01698	4.4	270
5534	Biotite	7.100 7.100	7.10	(1)0.01882 (2)0.01886	2.7 8.3	297 298
5560	Biotite	7.615 7.661	7.64	0.007959	4.2	132

TABLE 6. Rb/Sr DATA FOR CARBONIFEROUS GRANITES FROM THE URANNAH AND AUBURN COMPLEXES

GA No	Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr^{+}$	Age (m.y.)
AUBURN COMPLEX - WESTERN SIDE							
1067	Total rock	124.9	470.4	0.767	0.7078		
1190	Total rock	161.4	134.9	3.450	0.7199		
5361	Total rock	97.8	533.0	0.530	0.7065		
5554	Total rock	116.5	333.8	1.007	0.7083		
5555	Total rock	53.8	582.6	0.267	0.7053		
URANNAH COMPLEX							
472	Biotite	251.8	10.4	69.507	0.9848		284
812	Total rock	98.6	131.9	2.158	0.7140		
1072	Total rock	111.8	121.7	2.648	0.7150	0.7155	
5269	Total rock	204.5	210.1	2.809	0.7161	0.7168	
5270	Total rock	141.9 142.0	261.4 261.9	1.566 1.565	0.7112		
5289	Total rock	93.4	330.1	0.816	0.7081		

$^{+}$Denotes measured ratio

Table 6 (cont.)

GA No	Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr^{+}$	Age (m.y.)
5354	Total rock	75.4	167.6	1.298	0.7103		
5354	K feldspar	248.3	157.6	4.546	0.7235		
5354	Plagioclase	13.9	271.2	0.148	0.7052		
5354	Biotite	732.3	2.6	809.290	4.1623		290
5392	Total rock	134.8	257.0	1.513	0.7111		
5392	Biotite	827.1	9.9	242.060	1.8235		314
5396	Total rock	152.0	233.6	1.961	0.7135		
5396	K feldspar	451.8	195.4	6.673	0.7334	0.7336	
5396	Biotite	1054.5	6.9	439.825	2.7068		309

TABLE 7. K/Ar AND Rb/Sr MINERAL AGES OF THE CARBONIFEROUS GRANITES OF THE URANNAH COMPLEX

GA No		Mineral	K/Ar Age	Rb/Sr Age
472		Biotite	274	284
		Hornblende	269	
812		Biotite	270	
1072		Muscovite	273	
5354		Biotite	282	290
5392		Biotite	289	314
		Hornblende	294	
5396		Biotite	289	309
5270 cf.	(1189	Biotite	307	
	(	Hornblende	315	
	(5290	Hornblende	305	
5289		Hornblende	302	

+Denotes measured ratio

TABLE 8A. K/Ar AGES OF THE THUNDERBOLT GRANITE

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^*/^{40}K$	Ar Atm (%)	Age (m.y.)
473	Biotite	7.190 7.205	7.20	0.01699	4.7	270
5252	Biotite	7.543 7.508	7.53	0.01655	2.6	264
5253	Biotite	7.460 7.416	7.44	0.01632	3.7	261
5332	Biotite	7.446 7.357 7.403	7.40	0.01659	2.4	264
5338	Biotite	7.475 7.429	7.45	0.01619	4.1	259
5365	Biotite	7.401 7.387	7.39	0.01686	1.7	268
5378	Biotite	7.443 7.463	7.45	0.01682	15.0	268
5380	Biotite	7.500 7.492	7.50	0.01664	5.0	265

TABLE 8B. Rb/Sr AGES OF THE THUNDERBOLT GRANITE

GA No	Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Age (m.y.)
5252	Biotite	771.7	7.8	285.525	1.7988	260
5332	Biotite	603.5	5.8	302.016	1.9120	271

TABLE 9A. Rb/Sr DATA FOR THE URANNAH COMPLEX DYKES

GA No	Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr^+$
5502	Total rock	142.0	65.6	6.267	0.7284	
5503	Total rock	130.4	54.7	6.899	0.7307	0.7318

Table 9A (cont.)

GA No	Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr^{+}$
5504	Total rock	136.5	35.9	11.031	0.7447	0.7463
5505	Total rock	117.2	98.3	3.445	0.7183	0.7185
5506	Total rock	129.0	55.9	6.662		0.7295

TABLE 9B. K/Ar AGES OF THE URANNAH COMPLEX DYKES

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^{*}/^{40}K$	Ar Atm (%)	Age (m.y.)
5329	Hornblende	0.4243 0.4255	0.425	0.01593	15.6	255

TABLE 10. K/Ar AGES OF THE CRETACEOUS GRANITES AND VOLCANICS

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^{*}/^{40}K$	Ar Atm (%)	Age (m.y.)
OLDER INTRUSIONS						
1170	Biotite	7.178 7.198	7.19	(1)0.007079 (2)0.007062	4.2 3.4	117 117
1244	Hornblende	0.2225 0.2219	0.222	0.007420	32.2	123
"	Plagioclase	0.2412 0.2399	0.241	0.007013	45.4	116
5272	Plagioclase	0.1127 0.1119	0.112	0.008027	37.7	133
5330	Biotite	7.689 7.716	7.70	0.007560	5.2	125
"	Hornblende	0.4236 0.4233	0.423	0.007696	16.7	127
5331	Biotite	7.466 7.439	7.45	0.007397	3.8	123

+Denotes measured ratio

Table 10 (cont.)

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar*/^{40}K$	Ar Atm (%)	Age (m.y.)
5355	Biotite	7.384 7.414	7.40	0.007466	3.6	124
5356	Biotite	7.574 7.551	7.56	0.007517	15.2	124
"	Hornblende	0.5051 0.5061	0.506	0.007585	10.9	126
5358	Biotite	7.464 7.443	7.45	0.007466	13.5	123
5398	Biotite	7.832 7.865	7.85	0.007765	2.4	128
5399	Biotite	7.539 7.599	7.57	0.007446	10.0	123
5529	Biotite	7.545 7.570	7.56	0.007257	8.2	120
YOUNGER INTRUSIONS AND VOLCANICS						
1142	Hornblende	0.759 0.761	0.760	0.006588	8.8	110
1154	Hornblende	0.7873 0.7936	0.790	0.006939	16.5	115
5531	Hornblende	0.9956 0.9915	0.994	0.007012	31.5	116
5394	Whole rock	1.717 1.711	1.714	(1)0.006370 (2)0.005749	15.0 23.7	106 96
5553	Hornblende	0.3413 0.3408	0.341	0.006734	43.9	112

TABLE 11. K/Ar AGES OF THE LIZZIE CREEK VOLCANICS

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar*/^{40}K$	Ar Atm (%)	Age (m.y.)
5373	Plagioclase	0.1298 0.1288	0.129	0.01720	66.0	274

Table 11 (cont.)

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^{*}/^{40}K$	Ar Atm (%)	Age (m.y.)
5374	Plagioclase	0.6319 0.6290	0.630	0.01420	14.4	229
5375	Plagioclase	0.2255 0.2280	0.227	0.01653	45.6	264

TABLE 12. Rb/Sr DATA FOR THE PERMIAN- TRIASSIC VOLCANICS

GA No	Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr^{+}$
5519	Total rock	93.2	94.4	2.852	0.7151	0.7151
5520	Total rock	72.6	153.7	1.363		0.7097
5521	Total rock	117.9	126.2	2.692		0.7149
5522	Total rock	106.1	196.9	1.556	0.7106	0.7108
5523	Total rock	103.0	200.2	1.486	0.7112	0.7108
5524	Total rock	70.6	37.3	5.452	0.7245	0.7241
5525	Total rock	91.9	55.1	4.800	0.7214	0.7215
5532	Total rock	108.6	61.2	5.133	0.7233	0.7229

TABLE 13. Rb/Sr DATA FOR THE PROSERPINE VOLCANICS

GA No	Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr^{+}$
5507	Total rock	113.8	199.0	1.651	0.7067	0.7063
5508	Total rock	51.3	242.7	0.611	0.7047	0.7047
5511	Total rock	165.2	49.6	9.623	0.7193	0.7195
5512	Total rock	152.5	41.0	10.745	0.7204	0.7209
5539	Total rock	154.9	73.4	6.096	0.7133	0.7135

$^{+}$Denotes measured ratio

Table 13 (cont.)

GA No	Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr^+$
5546	Total rock	97.7	161.7	1.744	0.7063	0.7065
5547	Total rock	148.5	51.1	8.405	0.7180	0.7180
5552	Total rock	45.4	199.4	0.656	0.7049	

TABLE 14. K/Ar AGES OF THE PERMIAN GRANITES

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^*/^{40}K$	Ar Atm (%)	Age (m.y.)
MARLBOROUGH DISTRICT (GABBRO/DIORITE)						
1163	Hornblende	0.8944 0.8988	0.897	0.01528	4.8	245
1164	Biotite	6.789 6.790	6.79	(1)0.01544 (2)0.01534	42.9 1.5	249 246
"	Hornblende	0.7613 0.7618	0.762	0.01538	10.8	247
5263	Hornblende	0.6154 0.6138	0.615	0.01542	12.6	247
5264	Biotite	7.440 7.432	7.44	0.01512	1.8	243
"	Hornblende	0.6026 0.5990	0.601	0.01522	14.4	244
5265	Biotite	7.433 7.439	7.44	0.01512	2.5	243
5266	Biotite	7.326 7.327	7.33	0.01500	2.3	241
"	Hornblende	0.6470 0.6482	0.648	0.01484	11.6	238
MARLBOROUGH DISTRICT (GRANODIORITE/ADAMELLITE)						
1053A	Biotite	6.456 6.476	6.47	0.01429	40.9	230
"	Hornblende	0.6753 0.6729	0.674	0.01481	10.5	238

Table 14 (cont.)

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^{*}/^{40}K$	Ar Atm (%)	Age (m.y.)
1053B	Hornblende	0.6563 0.6565	0.656	0.01444	17.7	232
1054	Biotite	7.565 7.583	7.57	0.01498	2.9	240
"	Hornblende	0.6323 0.6269	0.630	0.01490	13.0	239
5256	Biotite	7.153 7.124	7.14	0.01459	8.9	235
"	Hornblende	0.6807 0.6817	0.681	0.01465	8.1	235
5257	Hornblende	0.8085 0.7996	0.804	0.01497	7.4	240
5259	Biotite	7.687 7.693	7.69	0.01475	1.4	237
5261	Biotite	7.807 7.772	7.79	0.01445	2.2	232
5359	Biotite	7.554 7.574	7.56	0.01465	5.1	235
"	Hornblende	0.7189 0.7200	0.719	0.01481	13.5	238
1068	Hornblende	1.0005 1.0006	1.001	0.01467	11.7	236
1069	Biotite	7.350 7.349	7.35	0.01477	2.6	237
"	Hornblende	0.9035 0.9023	0.903	0.01493	15.8	240
ROCKHAMPTON/AUBURN COMPLEX						
887	Hornblende	0.3188 0.3151	0.317	0.01555	28.3	249
1166	Biotite	7.520 7.568	7.54	0.01489	2.6	239
"	Hornblende	0.5858 0.5836	0.585	0.01511	14.7	242

Table 14 (cont.)

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^{*}/^{40}K$	Ar Atm (%)	Age (m.y.)
1167	Biotite	7.394 7.377	7.39	0.01485	5.9	239
"	Hornblende	0.4398 0.4385	0.439	0.01460	18.2	235
1168	Biotite	7.388 7.384	7.39	0.01461	3.3	235
1169	Biotite	7.409 7.367	7.39	0.01493	2.5	240
1249	Biotite	6.918 6.865	6.89	0.01470	2.3	236
"	Hornblende	0.5408 0.5389	0.540	0.01503	14.1	241
1250	Biotite	7.059 7.048	7.05	0.01455	2.0	234
"	Hornblende	0.5560 0.5595	0.558	0.01436	25.2	231
1369	Biotite	6.792 6.757	6.77	0.01473	2.3	237
"	Hornblende	0.4949 0.4959	0.495	0.01439	10.9	231
1370	Biotite	7.686 7.635	7.66	0.01558	1.6	249
5337	Biotite	7.747 7.707	7.73	0.01468	3.1	236
5340	Plagioclase	0.7300 0.7299	0.730	0.01425	12.7	229
5341	Biotite	7.445 7.435	7.44	0.01474	3.0	237
5342	Hornblende	0.7828 0.7821	0.782	0.01483	12.5	238
5343	Biotite	7.759 7.811	7.79	0.01563	7.4	250
5344	Biotite	7.921 7.867	7.89	0.01427	14.6	229

Table 14 (cont.)

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^{*}/^{40}K$	Ar Atm (%)	Age (m.y.)
5345	Biotite	7.586 7.619	7.60	0.01414	10.3	228
5348	Biotite	6.492 6.477	6.48	0.01465	28.8	235
"	Hornblende	0.3763 0.3765	0.376	0.01512	41.7	242
5350	Biotite	7.577 7.641	7.61	0.01449	9.5	233
"	Hornblende	0.7142 0.7217	0.718	0.01488	8.0	239
5351	Hornblende	0.4893 0.4909	0.490	0.01526	14.3	245
5352	Biotite	7.013 7.037	7.02	0.01413	10.1	228
"	Hornblende	0.7253 0.7341	0.730	0.01442	16.8	232
5353	Biotite	6.836 6.828	6.83	0.01418	11.1	228
"	Hornblende	0.7758 0.7790	0.777	0.01446	25.5	233
5357	Biotite	7.619 7.605	7.61	0.01417	5.1	228
5360	Biotite	7.527 7.558	7.54	0.01487	4.9	239
5362	Biotite	7.364 7.323	7.34	0.01468	4.1	236
5364	Biotite	7.144 7.132	7.14	0.01458	55.8	234
"	Hornblende	0.7101 0.7138	0.712	0.01443	33.4	232
5393	Biotite	7.333 7.398	7.37	0.01483	12.8	238

TABLE 15. K/Ar AGES OF THE TRIASSIC INTRUSIVES

GA No	Mineral	K (%)	Av. K (%)	$^{40}Ar^{*}/^{40}K$	Ar Atm (%)	Age (m.y.)
1155	Pyroxene	0.03	0.03	0.01361	71.7	220
1187	Pyroxene	0.0714 0.0716	0.072	0.01303	37.0	211
1245	Biotite	7.429 7.370	7.40	0.01340	2.6	216
"	Hornblende	0.3493 0.3485	0.349	0.01314	29.9	212
1246	Biotite	6.361 6.355	6.36	0.01338	2.6	216
"	Hornblende	0.3516 0.3505	0.351	0.01306	16.2	211
1287	Biotite	5.493 5.508	5.50	0.01370	2.3	221
"	Hornblende	0.3155 0.3152	0.315	0.01357	24.6	219
1248	Biotite	5.271 5.288	5.28	0.01364	3.0	220
5258	Muscovite	8.612 8.642	8.63	0.01347	2.4	218

SOLID GEOLOGY
BOWEN BASIN
QUEENSLAND

PLATE 1

Scale 1 : 1,000,000

10 0 10 20 30 40 50 60 80 KILOMETRES

10 0 10 20 30 40 50 MILES

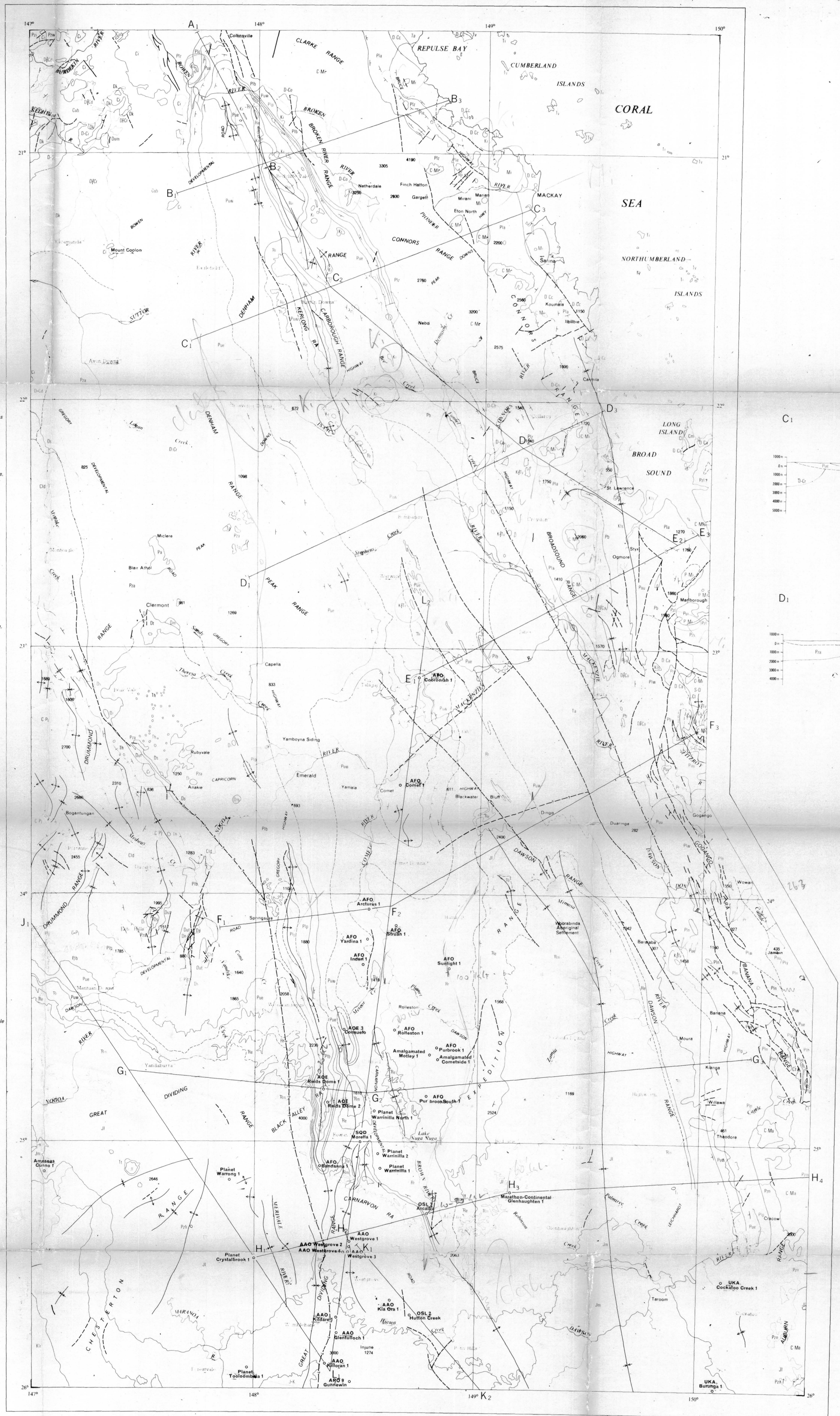
Sections
Scale V/H = 4

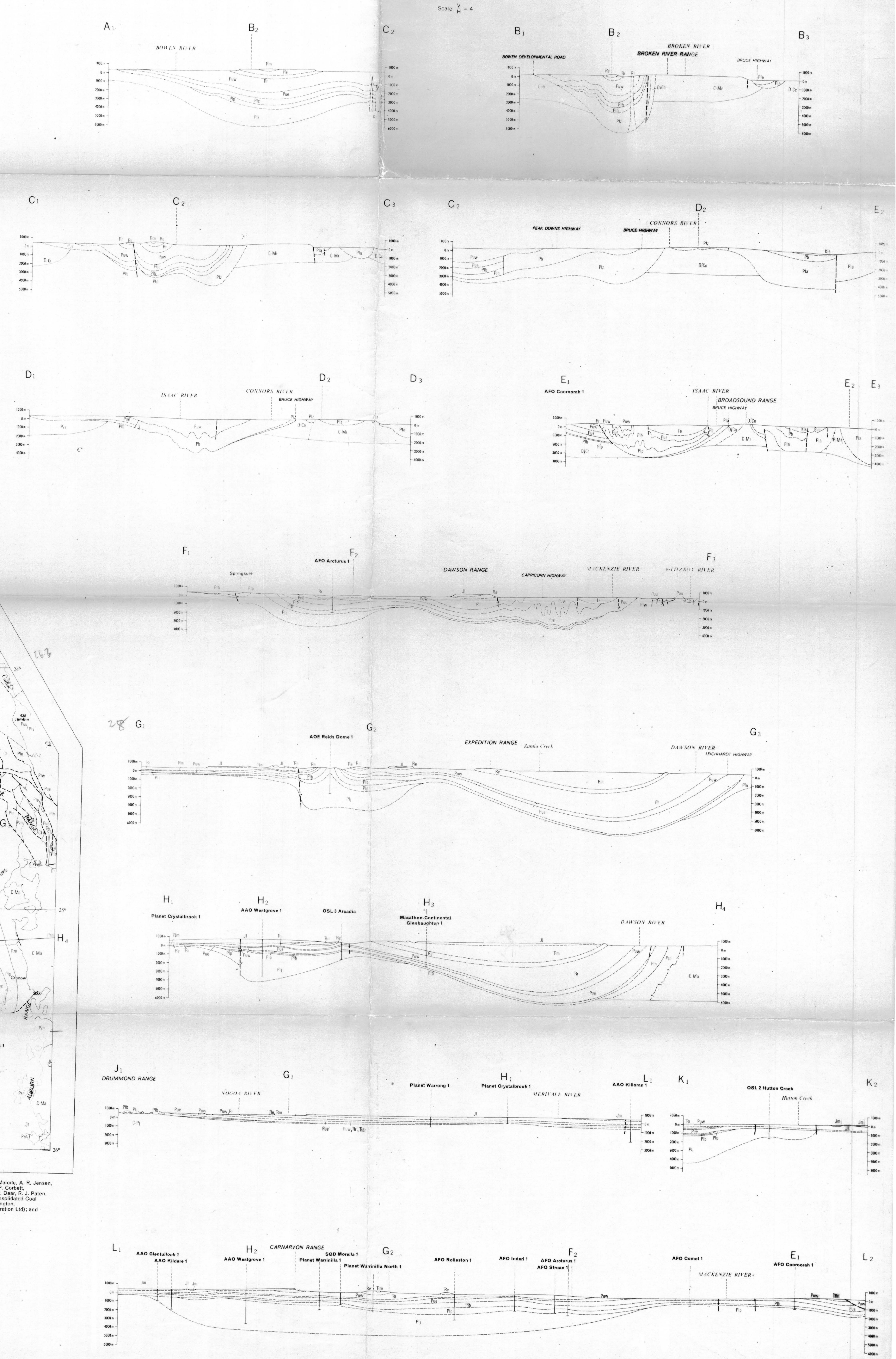
Reference

Cainozoic, Tertiary sediments, basalt and some volcanics omitted

CAINOZOIC	TERTIARY		Ta	Claystone, siltstone, sandstone, pebbly sandstone, conglomerate, sandstone erosion breccia.
			Tv	Rhyolite, dacite, trachyte, basalt flows and pyroclastics; minor intrusives
		Peak Range Volcanics	Tp	Rhyolite and trachyte flows and plugs
		Minerva Hills Volcanics	Tr	Alkaline trachyte and rhyolite flows, plugs, domes and dykes
		Hoy Basalt	Th	Olivine basalt plugs, with inclusions
		Tabor Gabbro	Tt	Olivine gabbro sill and stocks
	CRETACEOUS TO TERTIARY		K/Tv	Trachyte, rhyolite, dacite, andesite flows and pyroclastics; plugs and dykes
MESOZOIC	JURASSIC TO LOWER CRETACEOUS (GREAT ARTESIAN BASIN SEQUENCE)	Styx Coal Measures	Kls	Quartz sandstone, conglomerate, siltstone, carbonaceous shale; coal
		Roma Formation	Klr	Siltstone, sublabile sandstone, shale
		Gubberamunda, Orallo and Blythesdale Formations	J/K	Quartzose and sublabile sandstone, conglomerate, siltstone, claystone
		Injune Creek Group	Jm	Sublabile and lithic sandstone, siltstone, mudstone, claystone, thin coal seams, cone-in-cone limestone, concretions
		Precipice, Evergreen and Hutton Formations	Jl	Quartzose and sublabile sandstone, siltstone, mudstone, thin coal seams, conglomerate, chamositic mudstone and oolite
	CARBONIFEROUS TO MESOZOIC	Auburn Complex	C-Ma	Granodiorite; dacite dykes
		Urannah Complex	C-Mr	Granodiorite, granite, diorite, gabbro, amphibolite, rhyolite, porphyry; andesite and basalt dykes
	TRIASSIC	Moolayember Formation	Rm	Labile sandstone, calcareous in part, siltstone, shale, conglomerate
		Clematis Sandstone	Re	Cross-bedded, pebbly quartzose sandstone, red silty mudstone
		Rewan Formation	Rr	Red and green mudstone, green labile and sublabile sandstone, siltstone, volcanic pebble conglomerate
PALAEOZOIC			Pzs	Serpentinite
	PERMIAN (BOWEN BASIN SEQUENCE)	Blackwater Group	Puw	Volcano-lithic and feldspathic sandstone, conglomerate, mudstone, carbonaceous mudstone and shale, siliceous siltstone, chert, tuff, coal seams
		Rookwood Volcanics	Pr	Basaltic and spilitic pillow lava and agglomerate, chert, sediments
		Blair Athol Coal Measures	Pa	Coal, siltstone, sandstone
		Back Creek Group	Pb	Sandstone, siltstone, fossiliferous limestone and calcareous sandstone, tuff, volcano-lithic sandstone, sheared siltstone phyllite
		Blenheim Sub-group	Pue	Quartzose, sublabile and labile sandstone, conglomerate, siltstone, mudstone, shale, limestone, tuff, andesite, coal seams
		Boomer Formation	Puu	Interbedded lithic (volcanic) sandstone and siltstone, sheared siltstone, conglomerate, mudstone
		Gebbie Sub-group	Plb	Quartzose, and sublabile sandstone, fossiliferous calcareous siltstone and sandstone, conglomerate coal seams
		Collinsville Coal Measures	Plc	Quartzose and sublabile sandstone; conglomerate, siltstone, carbonaceous shale, coal
		Calen Coal Measures	Ple	Quartzose sandstone, siltstone, claystone, minor coal
		Tiverton Sub-group	Plp	Quartzose and sublabile sandstone, mudstone, siltstone, calcareous sandstone, limestone, coquinite
		Lizzie Creek Volcanics	Plz	Andesite, basalt, trachyte and minor acid flows and pyroclastics, conglomerate, greywacke, tuffaceous sandstone, siltstone
		Carmila Beds	Pla	Conglomerate, lithic greywacke, acid to intermediate flows and crystal and lithic tuffs, siltstone, mudstone
		Reids Dome Beds	Plj	Sandstone, siltstone, mudstone, carbonaceous shale, coal, conglomerate
	LOWER PERMIAN AND OLDER	Rannes Beds	Plw	Shale, siltstone, limestone, sheared siltstone, phyllite, slate, labile sandstone, lenses of acid to intermediate volcanics, chert, volcanics
		Camboon Andesite	Pln / Pzn	Andesite, basalt, crystal tuff, tuff, agglomerate limestone
	CARBONIFEROUS TO PERMIAN	Torsdale Beds	Ct	Lithic sandstone, conglomerate, siltstone, acid and intermediate lava, tuff, agglomerate
		Joe Joe Formation	C Pj	Lithic conglomerate, lithic sublabile sandstone, siltstone, minor shale
	UPPER CARBONIFEROUS	Bulgonunna Volcanics	Cub	Porphyritic rhyolite and dacite flows, crystal tuff, agglomerate, auto-breccia, welded tuff, lithic sandstone, siltstone
	UPPER DEVONIAN TO LOWER CARBONIFEROUS (DRUMMOND BASIN SEQUENCE)	Drummond Group and Upper Devonian Units	D/Cd	Quartz sandstone, siltstone, claystone, rhyolite flows and agglomerate
		Drummond Group	Cld	Quartzose and lithic sandstone, conglomerate, siltstone, mudstone, shale, tuff, algal and oolitic limestone
		Telemon Formation	Dut	Lithic conglomerate, lithic sandstone, multicoloured tuffaceous siltstone and shale, algal limestone
		Silver Hills Volcanics	Ds	Rhyolite, trachyte, andesite and basic flows and agglomerate; conglomerate, sandstone, shale
		Mt. Rankin Beds	D/Cr	Rhyolite, dacite flows, acid and intermediate pyroclastics, conglomerate, lithic (volcanic) sandstone, greywacke, siltstone
		Mt. Wyatt Beds	Duw	Lithic sandstone, siltstone, conglomerate
	MIDDLE DEVONIAN TO LOWER PERMIAN (YARROL BASIN SEQUENCE)		D-Ca	Limestone, mudstone, siltstone, sandstone, conglomerate
		Youlambie Conglomerate	Pl / Ply	Conglomerate, lithic and feldspathic sandstone, conglomeratic mudstone, siltstone; acid lava and tuff
		Neerkol Formation	Cu	Calcareous siltstone and sandstone, fossiliferous in part, conglomerate, mudstone
			Cl	Oolitic limestone, siltstone, mudstone, sandstone, chert
		Campwyn Beds	D Cc	Intermediate, basic and acid volcanics, siltstone, sandstone, conglomerate, limestone
	DEVONIAN TO CARBONIFEROUS	Connors Volcanics	D/Co	Rhyolite, dacite, trachyte, andesite flows and pyroclastics, tuffaceous sandstone and volcanic conglomerate, jointed and quartz-veined
	SILURIAN? TO DEVONIAN		S-D	Fossiliferous limestone; intermediate to basic flows and pyroclastics; chert
		Ukalunda Beds	Dk	Lithic and quartzose sandstone, shale, conglomerate, silicified limestone, chert, fossiliferous limestone lenses; some metamorphism
		Dunstable Volcanics	Dn	Green andesite lavas and pyroclastics, coralline limestone lenses, cherty shale
			Dm	Micaceous siltstone, pebbly sandstone, shale, coralline limestone, volcanics
		Theresa Creek Volcanics	Dt	Andesite, trychyandesite, rhyolite, dacite flows, crystal and lithic tuffs, arkose, lithic greywacke, siltstone
	MIDDLE TO LOWER PALAEOZOIC		Pzm	Metasediments
		Anakie Metamorphics	Pza	Quartz-mica schist, knotted schist, slate quartzite, crystalline limestone, sandstone, abundantly quartz-veined
		Mt. Windsor Volcanics	Pzw	Dacite, rhyolite, some andesite flows and pyroclastics and interbedded labile sediments; minor schist, gneiss and hornfels
			Pzl	Quartz-mica schist, phyllite, amphibolite, talc schist, quartzite hornfelsed quartz-mica schist, pyroxenite
			i	Intrusive. Age indicated by letter symbol.

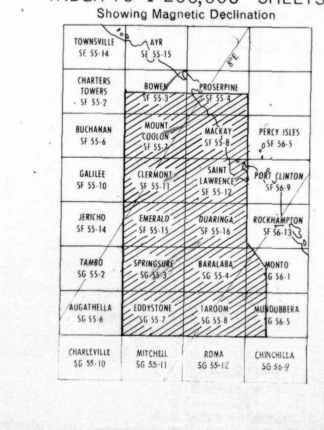
- Geological boundary
- Where location of boundaries is approximate, line is broken
- Strike and dip of strata
- Trend lines (air-photo interpretation)
- Structural boundary
- Anticline
- Syncline
- Monocline
- Fault
- Where location of faults is approximate line is broken
- strike and dip
- Strike and dip of overturned strata
- Trend lines
- Oil well
- Highway
- Road
- Railway
- Town
- Settlement
- Homestead



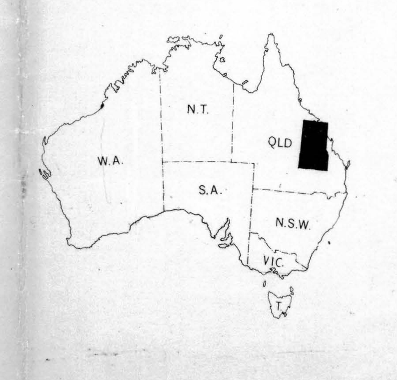


Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Base map compiled by the Bureau of Mineral Resources from air photographs, and information supplied by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force at 1 : 50,000 scale of Mt Coolon and Clermont 1 : 250,000 Sheet areas, and by Adastra Airways Pty Ltd at 1 : 85,000 scale of remainder of sheet; complete vertical coverage
Transverse Mercator Projection.

INDEX TO 1:250,000 SHEETS
Showing Magnetic Declination



Geology, to 1965, based on regional mapping of constituent 1 : 250,000 sheet areas, by E. J. Malone, A. R. Jensen, R. G. Mollan, F. Olgers, C. M. Gregory, J. J. Veevers, N. F. Exon, M. A. Randal, D. W. P. Corbett, J. A. J. Smit, A. W. Webb, J. M. Dickins (B.M.R.); A. G. Kirkegaard, V. R. Forbes, J. F. Dear, R. J. Paten, B. A. Coxhead, P. E. Bock, L. G. Cuttler (G.S.Q.); E. A. Webb, C. E. Crapp (Bowen Consolidated Coal Mines Pty Ltd); D. King, P. Goscombe, L. Hansen (Utah Development Co.); S. S. Derrington, K. H. Morgan (Mines Administration Pty Ltd); W. C. White, G. A. Brown (Ampol Exploration Ltd); and P. McKenzie, J. Faulkner (Broken Hill Pty Ltd).
Compiled 1968 by: E. J. Malone
Cartography by Geological Branch B.M.R.
Printed by:



To accompany Record 1971/64

REFERENCE

Cainozoic, Tertiary sediments, [redacted]

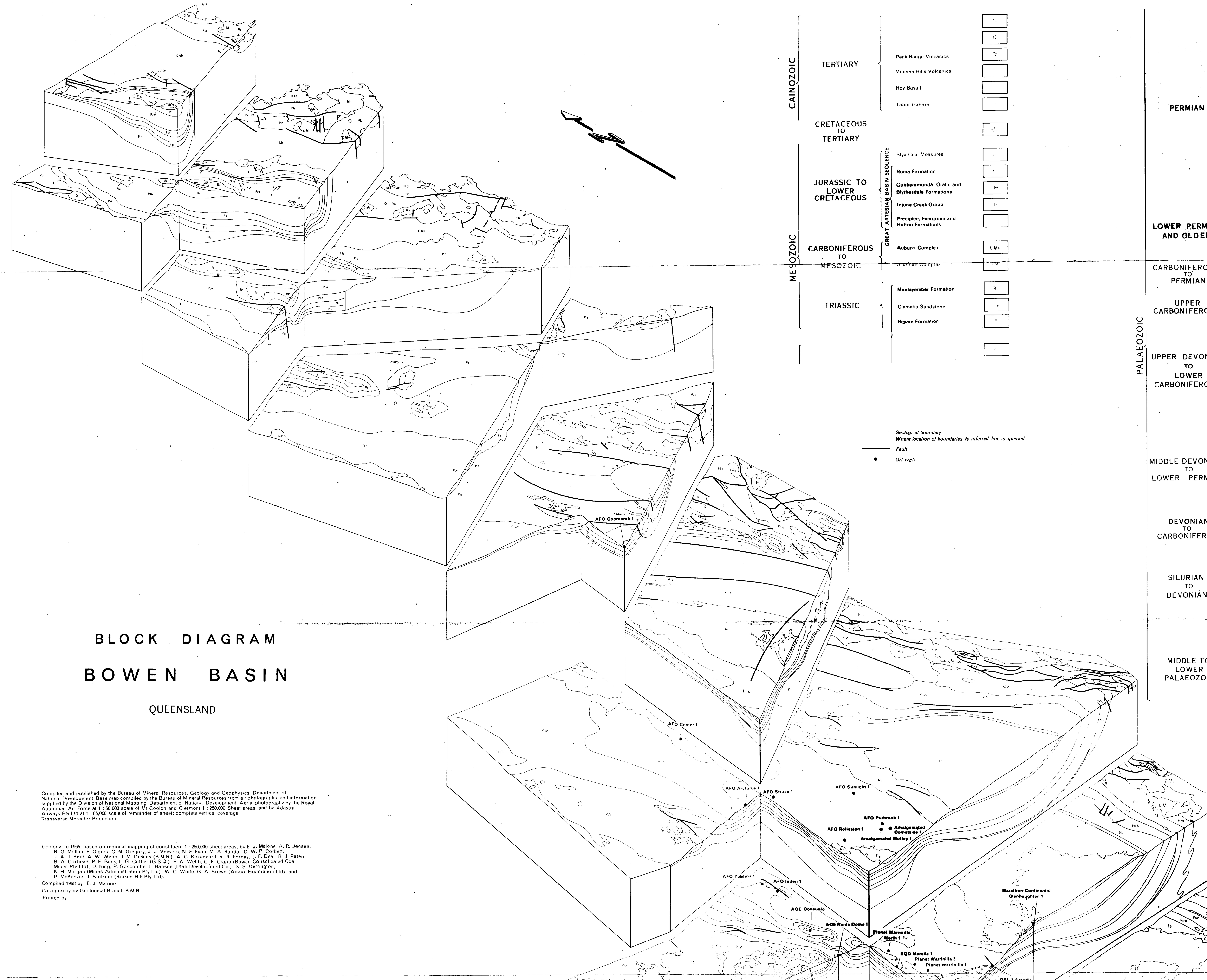
CAINOZOIC	TERTIARY			
			Peak Range Volcanics	
			Minerva Hills Volcanics	
			Hoy Basalt	
			Tabor Gabbro	
	CRETACEOUS TO TERTIARY			
MESOZOIC	JURASSIC TO LOWER CRETACEOUS	GREAT ARTESIAN BASIN SEQUENCE	Styx Coal Measures	
			Roma Formation	
			Gubberamunda, Orallo and Blythesdale Formations	J-K
			Injune Creek Group	
			Precipice, Evergreen and Hutton Formations	
	CARBONIFEROUS TO MESOZOIC		Auburn Complex	C Ma
			Urannah Complex	
	TRIASSIC		Moolayember Formation	Rm
			Clematis Sandstone	
			Rewan Formation	
PALAEOZOIC	PERMIAN	BOWEN BASIN SEQUENCE	Blackwater Group	Puw
			Rookwood Volcanics	
			Blair Athol Coal Measures	Pa
			Back Creek Group	Pb
			Blenheim Sub-group	Pue
			Boomer Formation	Puu
			Gebbie Sub-group	Plh
			Collinsville Coal Measures	Plc
			Calen Coal Measures	Ple
			Tiverton Sub-group	Plp
			Lizzie Creek Volcanics	Plz
			Carmila Beds	Pla
			Reids Dome Beds	Plj
	LOWER PERMIAN AND OLDER		Rannes Beds	Plw
			Camboon Andesite	Pln / Pzn
	CARBONIFEROUS TO PERMIAN		Torsdale Beds	
			Joe Joe Formation	C Pj
	UPPER CARBONIFEROUS		Bulgonunna Volcanics	Cub
	UPPER DEVONIAN TO LOWER CARBONIFEROUS	DRUMMOND BASIN SEQUENCE	Drummond Group and Upper Devonian Units	D-Cd
			Drummond Group	Cld
			Telemon Formation	Dut
			Silver Hills Volcanics	Ds
			Mt. Rankin Beds	D/C
			Mt. Wyatt Beds	Dum
	MIDDLE DEVONIAN TO LOWER PERMIAN	YARROL BASIN SEQUENCE		D Ca
			Youlambie Conglomerate	Pl / Plv
			Neerkol Formation	Cu
				Ci
			Campwyn Beds	D Cc
	DEVONIAN TO CARBONIFEROUS		Connors Volcanics	D/C
	SILURIAN ? TO DEVONIAN			S-D
			Ukalunda Beds	Dk
			Dunstable Volcanics	Dn
				Dm
			Theresa Creek Volcanics	Dt
	MIDDLE TO LOWER PALAEOZOIC			Pzm
			Anakie Metamorphics	Pza
			Mt. Windsor Volcanics	Pzw
				Pzl

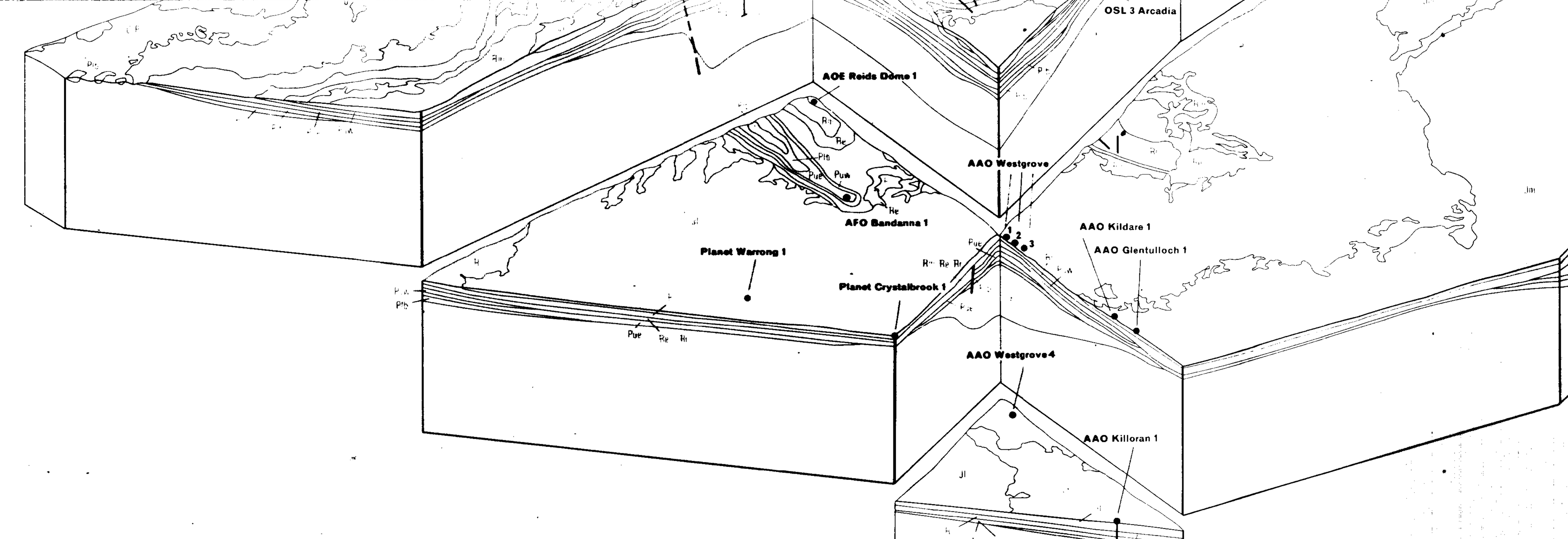
Geological boundary
Where location of boundaries is inferred line is queried
Fault
Oil well

BLOCK DIAGRAM

BOWEN BASIN

QUEENSLAND





Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Base map compiled by the Bureau of Mineral Resources from air photographs, and information supplied by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force at 1 : 50,000 scale of Mt Coolon and Clermont 1 : 250,000 Sheet areas, and by Adastra Airways Pty Ltd at 1 : 85,000 scale of remainder of sheet; complete vertical coverage Transverse Mercator Projection.

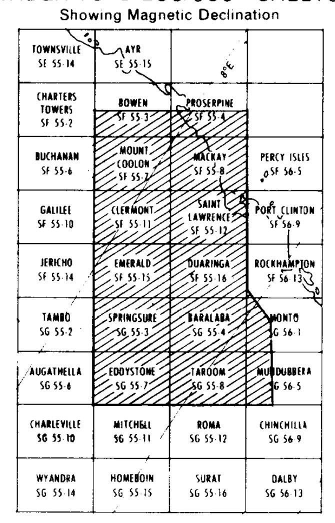
Geology, to 1965, based on regional mapping of constituent 1 : 250,000 sheet areas, by E. J. Malone, A. R. Jensen, R. G. Mollan, F. Olgers, C. M. Gregory, J. J. Veevers, N. F. Exon, M. A. Randal, D. W. P. Corbett, J. A. J. Smit, A. W. Webb, J. M. Dickins (B.M.R.); A. G. Kirkegaard, V. R. Forbes, J. F. Dear, R. J. Paten, B. A. Coxhead, P. E. Bock, L. G. Cuttler (G.S.Q.); E. A. Webb, C. E. Crapp (Bowen Consolidated Coal Mines Pty Ltd); D. King, P. Goscombe, L. Hansen (Utah Development Co.); S. S. Derrington, K. H. Morgan (Mines Administration Pty Ltd); W. C. White, G. A. Brown (Ampol Exploration Ltd); and P. McKenzie, J. Faulkner (Broken Hill Pty Ltd).

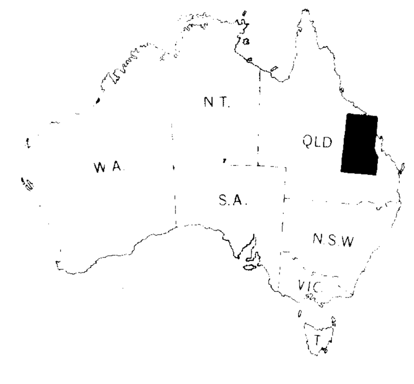
Compiled 1968 by: E. J. Malone

Cartography by Geological Branch B.M.R.

Printed by:

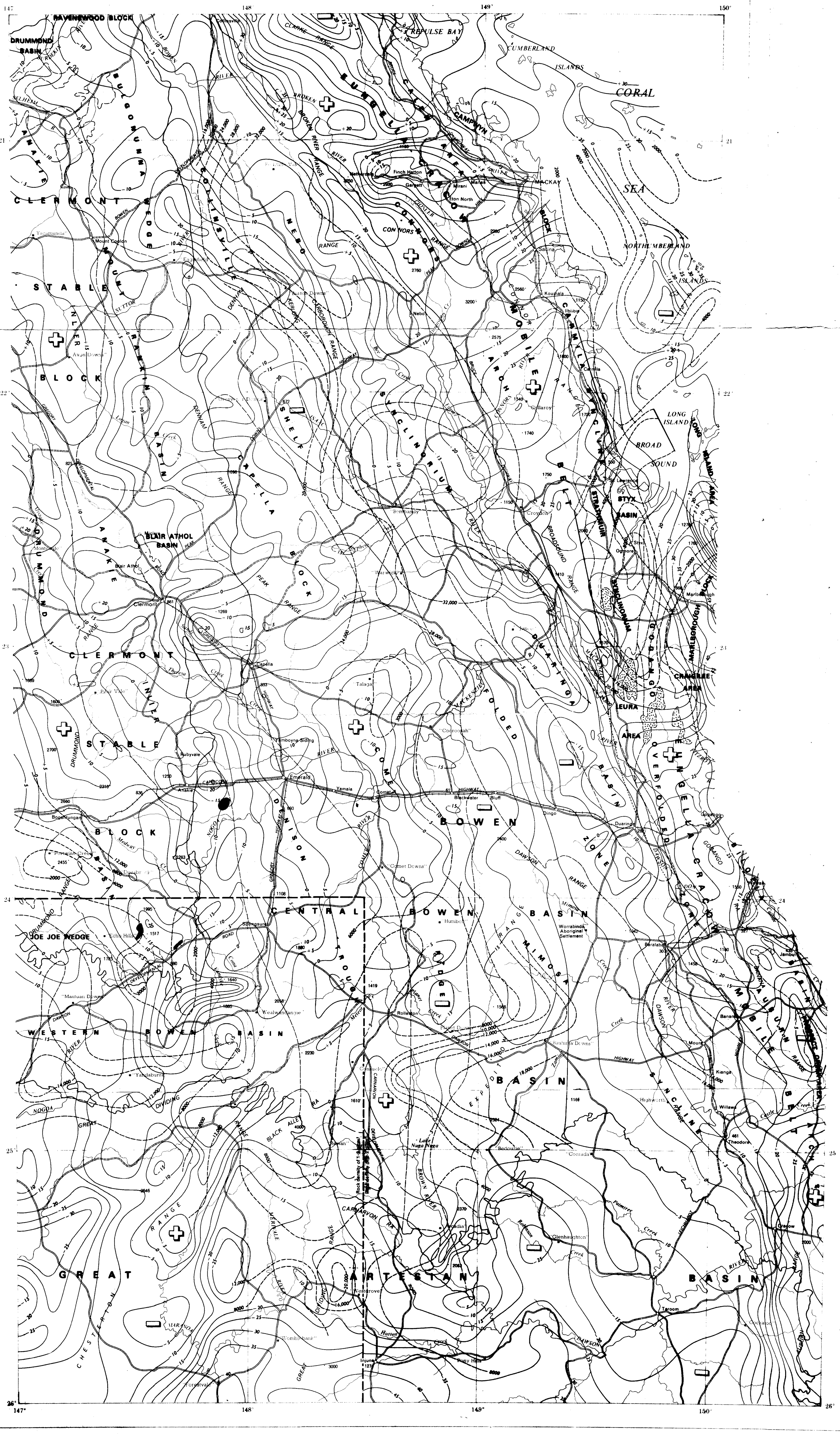
INDEX TO 1 250 000 SHEETS
Showing Magnetic Declination





To accompany Record 1971/64

TECTONIC UNITS AND STRUCTURAL SUBDIVISIONS
(WITH AEROMAGNETIC AND GRAVITY DATA)
BOWEN BASIN
QUEENSLAND



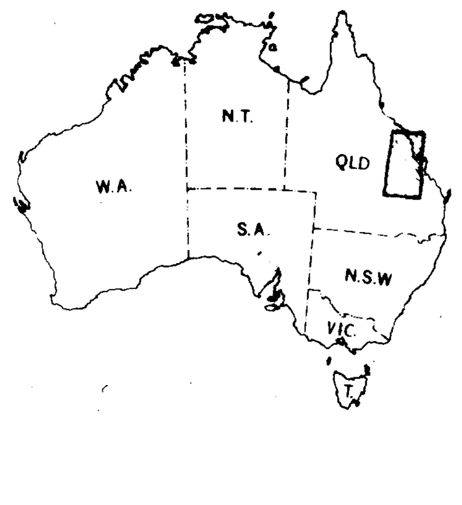
Scale 1:1,000,000

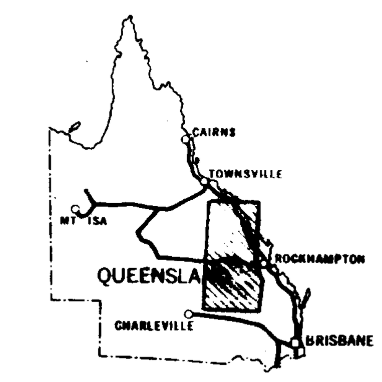
20 0 20 40 60 80 100 KILOMETRES

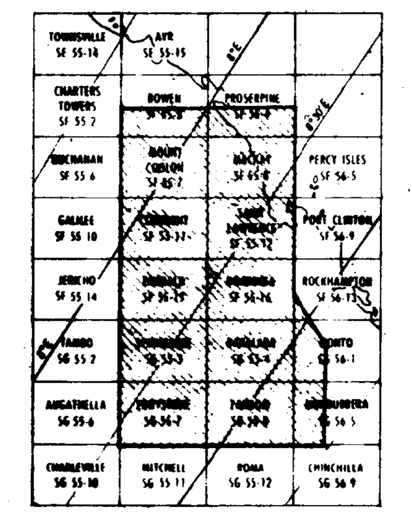
20 0 20 40 60 MILES

Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Base map compiled by the Bureau of Mineral Resources from air photographs, and information supplied by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force at 1 : 50,000 scale of Mt Coolon and Clermont 1 : 250,000 Sheet areas, and by Adastra Airways Pty Ltd at 1 : 85,000 scale of remainder of sheet; complete vertical coverage
Transverse Mercator Projection.

Geology, to 1966, based on regional mapping of constituent 1 : 250,000 sheet areas, by E. J. Malone, A. R. Jensen, R. G. Mollan, F. Olgers, C. M. Gregory, J. J. Veevers, N. F. Exon, M. A. Randal, D. W. P. Corbett, J. A. J. Smit, A. W. Webb, J. M. Dickins (B.M.R.); A. G. Kirkegaard, V. R. Forbes, J. F. Dear, R. J. Paten, B. A. Coxhead, P. E. Bock, L. G. Cuttler (G.S.Q.); E. A. Webb, C. E. Crapp (Bowen Consolidated Coal Mines Pty Ltd); D. King, P. Goscombe, L. Hansen (Utah Development Co.); S. S. Derrington, K. H. Morgan (Mines Administration Pty Ltd); W. C. White, G. A. Brown (Ampol Exploration Ltd); and P. McKenzie, J. Faulkner (Broken Hill Pty Ltd).
Cartography by Geological Branch, BMR
Drawn by
Printed by







Tectonic unit boundary

Structural unit boundary

Pre-Permian inliers

Middle Devonian or older inliers

Possible fault

— 5 — Isogals

Gravity anomaly — relative high

Gravity anomaly — relative low

Rock density boundary

Highway

Road

Railway

Town

Settlement

"Echo Hills" Homestead

Magnetic basement contours from Wells and Milsom (1966), Bureau of Mineral Resources, Geology and Geophysics.

Gravity reduced from 1 : 250,000 and 1 : 500,000 Series, Geophysical Branch, B.M.R.

Station Bouguer anomaly reliability: standard deviation <1 milligal

Rock density of 1·9 g/cm^3 used for computations of Springsure and Eddystone 1 : 250,000 Sheet areas; 2·2 g/cm^3 for remainder.

Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or the Geological Survey of Queensland, Brisbane

To accompany Record 1971/64