COMMONWEALTH OF AUSTRALIA

STATE OF QUEENSLAND



REPORT No. 121

# The Geology of the Duaringa and Saint Lawrence 1:250,000 Sheet Areas, Queensland



BY

E. J. MALONE and F. OLGERS (Bureau of Mineral Resources)

AND

A. G. KIRKEGAARD (Geological Survey of Queensland)

*Published by*
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COMMONWEALTH OF AUSTRALIA

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## SUMMARY

The Duaringa and Saint Lawrence Sheet areas are mainly occupied by the Bowen Basin, including part of the structurally deformed eastern margin of the basin where the Permian sequence is complexly related to pre-Permian rocks of many ages.

The oldest rocks in the area are the metamorphics of the Marlborough area, which are possibly Lower Palaeozoic. They, and possibly the extensive serpentinite mass associated with them, were block-faulted into approximately their present position during the Lower Permian. The metamorphics and serpentinite were intruded by gabbro and acid intrusives in the Upper Permian.

Silurian-Devonian volcanics and limestone were deposited in the east of the area and folded. They acted as source for, and basement beneath, Devonian, Carboniferous, and Permian rocks, were involved in their deformation, and are now exposed in the core of the Craigilee Anticline near the eastern margin of the Duaringa Sheet area and as inliers surrounded by Permian rocks farther west.

Upper Devonian and Carboniferous sediments were deposited in the eastern part of the area, near the western limit of the Yarrol Basin. Relationships around the Craigilee Anticline indicate that the Silurian-Devonian rocks formed an emergent area which was progressively overlapped by the Yarrol Basin sequence.

The Connors Volcanics are mostly massive volcanics of Lower Carboniferous or older age, which formed islands in the Lower Permian sea and have greatly influenced the subsequent deformation of Lower Permian sediments. They crop out in a linear zone - the Connors Arch and its south-southeasterly extension - in which the Lower Permian or older Rannes Beds and Camboon Andesite are also exposed. The Rannes Beds overlie the Connors Volcanics in the centre of this zone and interfinger with and overlie the Camboon Andesite at its southern end.

The Lizzie Creek Volcanics and Carmila Beds accumulated in the early Lower Permian west and east of the Connors Arch, initially as terrestrial volcanics with some freshwater sediments, and finally in a marine environment. The sea transgressed over most of the area (at the end of the Sakmarian?) and deposition of the Back Creek Group began, accompanied by continued vulcanism in some areas. The basal part of the Back Creek Group was deposited over some of the Duaringa Sheet area, but this area was mainly land during the remainder of the Lower Permian.

In the west, deposition of the Back Creek Group continued throughout the late Lower Permian into the Upper Permian. The group is relatively thin over the Comet Ridge and thickens westwards into the Denison Trough and probably northeastwards into the Folded Zone. Rock types in the group reflect marine transgressions and regressions. The basal unit, the Tiverton Subgroup, consists of marine mudstone and minor limestone. It is overlain by the Gebbie Subgroup, consisting of two fluviatile or marine littoral sandstone units separated by a marine mudstone unit. The uppermost unit, the Blenheim Subgroup, consists of marine mudstone and sandstone overlain by coal measures deposited in marine and brackish water probably during the final withdrawal of the sea.

The marine Youlambie Conglomerate was deposited in the east of the Duaringa Sheet area, possibly before the sea entered the Bowen Basin. Its depositional area was bounded to the west by a landmass of Rannes Beds and volcanics. The sea transgressed the landmass in the early Upper Permian, when the spilitic pillow lavas of the Rookwood Volcanics were extruded in the east, neritic limestone of the Oxtrack Formation was deposited in the southeast, and the Boomer Formation was deposited over most of the eastern part of the area. The Boomer Formation, which was probably continuous with the Blenheim Subgroup deposited farther west, represents the last Bowen Basin sedimentation in the east, where uplift and the end of sedimentation possibly coincided with withdrawal of the sea from the Bowen Basin.

In the late Upper Permian, the Blackwater Group was deposited in fluviatile, lacustrine, and paludal environments in the Bowen Basin, which had contracted to west of the linear zone occupied by the Rannes Beds, Connors Volcanics, and Camboon Andesite. Deposition was thin but apparently complete over the Comet Ridge and much thicker in a trough which later became the Folded Zone. The last deposition in the Bowen Basin in this area was in the Triassic, when the Rewan Formation and the Clematis Sandstone were deposited in the trough of the Mimosa Syncline.

An outlier of the Lower Jurassic Precipice Sandstone unconformably overlies the Clematis Sandstone in the southern part of the Duaringa Sheet area. This fluviatile blanket sand at the base of the Great Artesian Basin sequence was deposited after moderate folding and considerable uplift and erosion of the Bowen Basin sequence.

The Lower Cretaceous Styx Coal Measures were probably deposited over much of the eastern part of the area, but are preserved now only in the fault-bounded Styx Basin and in a few outliers. About 3500 feet of Tertiary and possibly Cretaceous sediments accumulated in the Duaringa Basin, west of the Dawson and Mackenzie Rivers, and separated from the Folded Zone to the west by a normal fault.

Six structural zones are recognized in the Bowen Basin and three in the older rocks in the east. Several periods of folding, mainly the result of compressive stress from the east, have deformed the sediments, culminating in a period of overthrust faulting, folding, uplift, and intrusion in the Lower Cretaceous. The Folded Zone was probably folded at this time, possibly as a result of gravity tectonics associated with uplift of the Connors Arch.

Considerable minor igneous activity took place at the end of the Cretaceous and during the Tertiary. Displaced laterite profiles in the Marlborough area, and the faulted Duaringa Basin containing mainly Tertiary sediments, indicate considerable faulting in the Tertiary.

Intrusive rocks are not widespread. Potassium-argon ages on some of the intrusives from this and adjacent areas indicate three groups of intrusion: one group about 300 million years old which intrudes the Connors Volcanics; a second, about 240 million years old, which intrudes Rookwood Volcanics and older rocks in the east of the area; and a third group, about 125 million years old, which intrudes Bowen Basin sediments in the Folded Zone. Relationships of the Lower Cretaceous intrusives to the folded Bowen Basin sequence suggest that intrusion and folding were contemporaneous.

Vast quantities of coal are contained in the Rangal Coal Measures, the top formation of the Blackwater Group. The rank and coking properties vary with the degree of structural deformation: semi-bituminous coking and non-coking coals are found in the west and semi-anthracite in the Folded Zone. Locally important coal seams also occur in the basal part of the Blackwater Group and in the German Creek Coal Measures at the top of the Back Creek Group in the west of the Duaringa Sheet area.

Only insignificant quantities of hydrocarbons were found in the two oil exploration holes drilled in the west of the Duaringa Sheet area. Most of the rocks of the Folded Zone and farther east are too deformed and metamorphosed to be prospective for petroleum. The rocks west of the Mimosa Syncline are prospective but may lack permeable reservoir rocks.

Concentrations of nickel are being sought in the laterite profiles developed on the serpentinite of the Marlborough Block, but no economic deposits have been reported. Minor mineralization is widespread in the east.

## INTRODUCTION

The Duaringa/Saint Lawrence area includes about 11,000 square miles of land and is bounded by latitudes 22°S and 24°S and by longitudes 148°30'E and 150°E; Rockhampton, the nearest large town, is 50 miles to the east. The area covers the central part of the Bowen Basin and extends beyond its eastern margin, where the geology is complex and involves both the Bowen Basin and Yarrol Basin sequences, as well as inliers of older volcanics and a fault-block of metamorphics and intrusives.

The Sheet areas were mapped in 1962 as part of a regional survey of the Bowen Basin to assist in the search for oil. The Duaringa Sheet area and the southern half of the Saint Lawrence Sheet area were mapped by E.J. Malone, R.G. Mollan, and F. Olgers (BMR), and A.G. Kirkegaard (GSQ), and the northern half of the Saint Lawrence Sheet area by A.R. Jensen and C.M. Gregory (BMR), and V.R. Forbes (GSQ). The geology of the southeast of the Duaringa Sheet area was amended and several sections were measured in 1963 by the Baralaba Party (Olgers, Webb, Smit, & Coxhead, 1966; Malone & Bastian, 1964). Olgers, Malone, and Kirkegaard re-examined the northeastern part of the Duaringa Sheet area and the eastern part of the Saint Lawrence Sheet area in 1964. In 1965, Malone and Kirkegaard re-examined the area east of the Fitzroy River and Jensen measured sections in the Blackwater area. The western half of the Duaringa 1:250,000 Sheet incorporates some mapping by Derrington & Morgan (1959, a and b) of Mines Administration Pty Ltd and some by King, Goscombe, and Hansen of Utah Development Co. (King, 1963).

The Central Railway and the Capricorn Highway cross the Duaringa Sheet area from east to west. Five small towns, Duaringa, Dingo, Bluff, Blackwater, and Comet, are on the railway. They serve the pastoral and timbercutting industries of the surrounding areas and are the focal points of networks of gravel roads and vehicle tracks giving access to areas north and south of the railway.

The North Coast Railway and the Bruce Highway cross the Saint Lawrence Sheet area. They run west from the southeast corner and then north to the northern margin. North of Saint Lawrence, the railway is close to the coast, and the highway is 20 to 30 miles inland. Marlborough, Ogmore, and Saint Lawrence are small towns on the railway, and are linked by vehicle tracks to the various homesteads and the Bruce Highway.

Most of the area is accessible by car during the dry season; exceptions are the Blackdown Tableland and the ranges to the south, and parts of the Boomer and Connors Ranges, which can only be traversed on horseback or on foot. In some parts of the Boomer Range, the scrub cover is impenetrable.

Most of the area has an annual rainfall of 20 to 30 inches; 30 to 40 inches of rain falls in the coastal part of Saint Lawrence, east of the Connors Range. Vehicular travel away from main roads may be impossible for long periods during December to April, when most of the rain falls. The winter months are mainly dry, with fine cool days and cold, often frosty nights.

Cattle raising is the main industry in the area. In recent years, some of the larger holdings were resumed and subdivided into smaller blocks to promote closer settlement and better land use. Scrub-clearing operations are being encouraged by the State Government for the same reasons. Wheat and other crops are grown in the southeast of the Duaringa Sheet area and some sugar cane is grown near the northern margin of the Saint Lawrence Sheet area.

Timbercutting and coal mining are moderately important industries in the area. Saw mills are operating at Duaringa and Dingo. Utah Development Company are expected to begin open-cut mining of coking coal near Blackwater in 1967 and are continuing the search for other deposits, as are other companies. Many of the population are engaged in maintenance and construction work on the railways and the roads.

Both Sheet areas are covered by air-photographs at 1:85,000 scale taken by Adastra Airways Pty Ltd in 1960. These photographs were used by the Division of National Mapping to produce uncontrolled photomosaics at photoscale and 1:250,000, compilation sheets at 1:93,000 controlled by slotted templet assemblage, and planimetric maps at 1:250,000. Other maps covering the area include cadastral maps at 1 inch to 2 miles and 1 inch to 4 miles published by the Department of Lands, Brisbane, and planimetric maps at 1 inch to 4 miles, published by the Army. Before field work started, W.J. Perry of the Bureau of Mineral Resources and B. de Lassus St Genies of the Institut Français du Pétrole, Mission in Australia, produced photogeological maps at 1:250,000 of the Sheet areas. These maps were used as guides during the field work.

## Previous investigations

The 1962 survey, with its later continuations, was the first to map the whole of the two Sheet areas. The small amount of work done before 1962 consisted of detailed mapping of small areas and some reconnaissance traverses; all relevant publications are listed in the References (p. 89 ). Figure 1 shows the location of geophysical surveys covering parts of the area. The flight lines and gravity stations for the Bureau of Mineral Resources aeromagnetic (Wells & Milsom, 1966) and gravity (Darby, 1966; Lonsdale, 1965) surveys covering the whole area are not shown.

# PHYSIOGRAPHY

The physiography of the area is illustrated by a block diagram (Fig. 2). The area consists mainly of 6 topographic units which are described below. The boundaries between the topographic units are vague and are not shown on Figure 2.

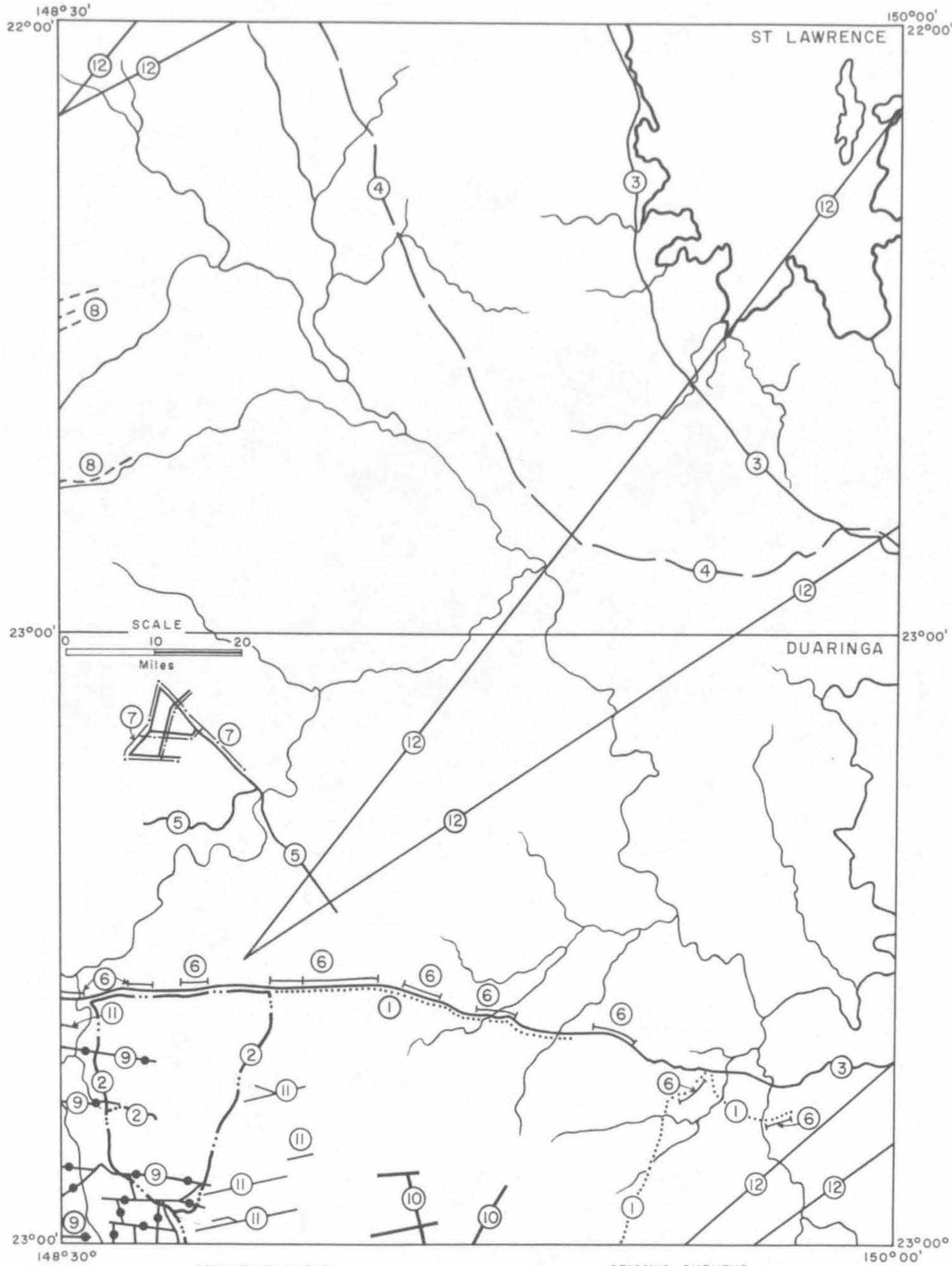
Dissected tableland occupies large areas, mainly in the southwest of the Duaringa Sheet and in a belt from the southeast of the Duaringa Sheet to the northwest of the Saint Lawrence Sheet. The tableland, which is formed by a sheet of Tertiary sediments, is gently undulating and, along the railway line, ranges in height from 500 feet above sea level at Walton in the west to 280 feet above sea level at Duaringa. Breakaways occur in many places along the edges of the tableland, and mesas are common.

Rolling plains country occurs mainly in the northwest of the Duaringa Sheet area and in the southwest of the Saint Lawrence Sheet. It occupies the areas between the tableland and the flood plains and alluvial flats along the main rivers. The vegetation is medium to dense, with dense brigalow patches in places.

Flood plains occur along the Mackenzie, Dawson, Isaac, Connors, and Comet Rivers and to a lesser extent along the Fitzroy River. The plains are most extensive where the Isaac River joins the Mackenzie River.

The Blackdown Tableland in the south rises steeply to 1500 feet above the surrounding country. It is extremely dissected and slopes gently to the south. The margins are steep scree-covered slopes, topped by almost vertical broken cliffs (Pl. 5, fig. 2). The tableland is densely timbered and cannot be traversed by vehicle.

The main ranges, comprising from north to south the Connors, Broadsound, and Gogango Ranges, extend across both Sheet areas, a distance of 160 miles. In the north, the ranges have a maximum width of 25 miles; they are only 5 miles wide where the Fitzroy River cuts them, northeast of Duaringa. The ranges are rugged, and moderately to densely vegetated, and can be crossed in only a few places. They become progressively lower and narrower to the south, though local relief is considerable everywhere. The highest peak, 1400 feet above sea level, is in the Broadsound Range, 30 miles west-northwest of Marlborough. The ranges form a watershed which is breached only by the Fitzroy River, 12 miles northeast of Duaringa.




GRAVITY SURVEYS

(1) *Warren, 1959*

(2) *Oldham, 1958*

(3) *Marshall and Narain, 1954*

(4) *Eastern Australian Regional Net*

(5) *Burbury, 1959*

AEROMAGNETIC SURVEY

(12) *Hartman, 1962*

SEISMIC SURVEYS

(6) *Robertson, 1961*

(7) *Moss and Morton, 1961*

(8) *United Geophysical Corporation, 1963*

(9) *Geophysical Service Int., 1964*
*Seismograph Service Ltd, 1964*

(10) *Marathon Petroleum, 1962, 1963*

(11) *Geophysical Service Int., 1966*

Figure 1 Location of geophysical surveys.

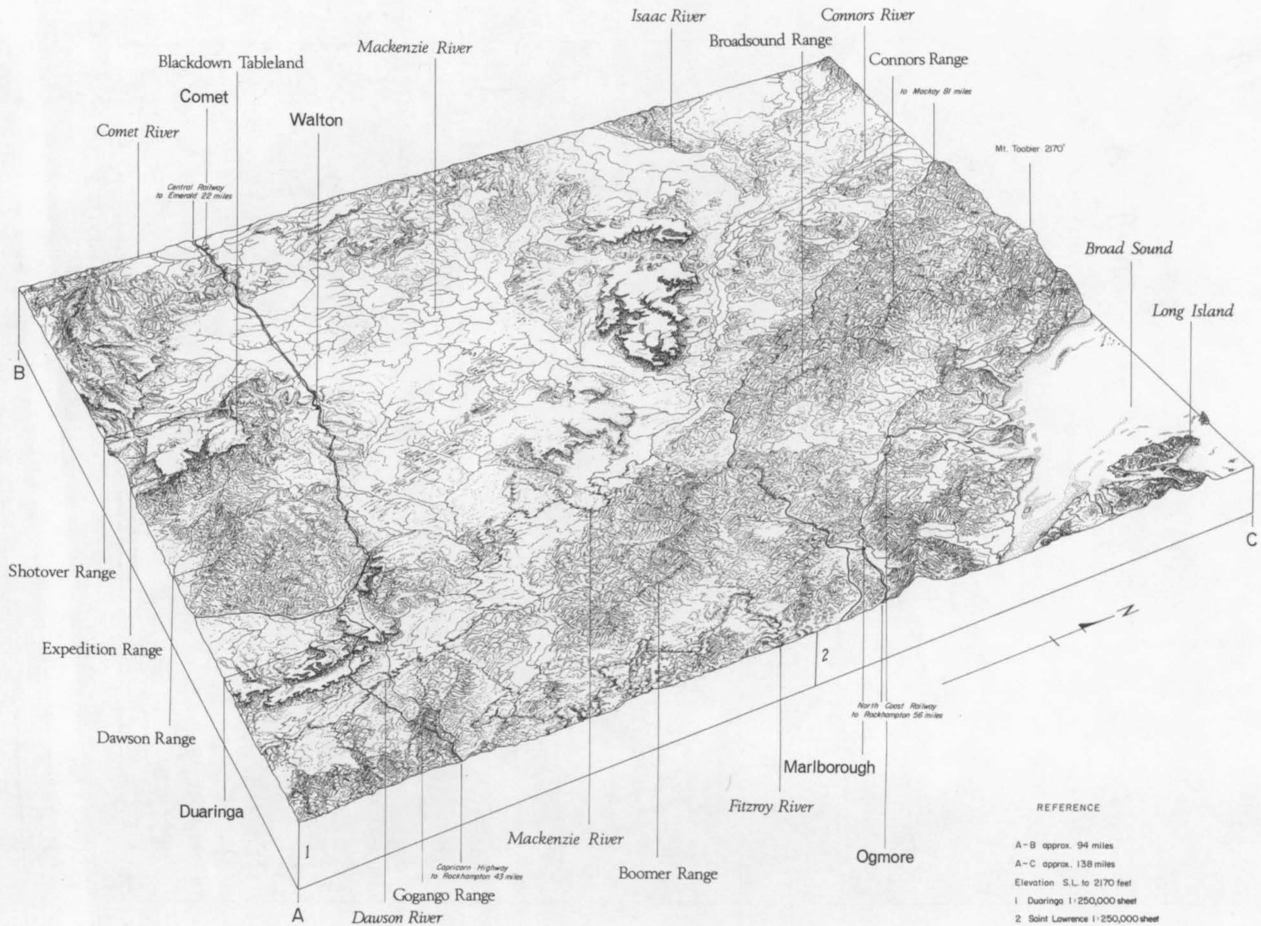



Figure 2 Physiographic block diagram.

The area east of the ranges has a varied topographic expression. Gently undulating moderately vegetated low country lies in a narrow belt directly to the east of the ranges. Coastal swamps occur near the mouths of streams emptying into Broad Sound. Range country, up to 1200 feet above sea level, occurs in an area east of Ogmore in the Saint Lawrence Sheet area, and a group of rugged densely timbered mountains occurs around Marlborough.

### Drainage

Nearly all the area lies within the Fitzroy River drainage basin. The main drainage channels are the Mackenzie, Dawson, Isaac, Connors, Comet, and Fitzroy Rivers. The Mackenzie River meanders widely and has numerous oxbow lakes. In the western part of the Duaringa Sheet, where the river flows northeast, its course may be structurally controlled. Near Manly homestead in the south of the Saint Lawrence Sheet, the Isaac River, which has the Connors River as its main tributary, joins the Mackenzie River, which then flows southeast along the western edge of the Boomer Range. The Dawson River flows northwest along the western edge of the Gogango Range and joins the Mackenzie River 9 miles northeast of Duaringa to form the Fitzroy River. The Fitzroy River has a winding course, which is probably largely structurally controlled. The river flows east to the eastern boundary of the Duaringa Sheet and then north along the Sheet boundary. The Comet River flows north along the western boundary of the Duaringa Sheet to join the Mackenzie River at Comet. A small area northeast of the main ranges in the Saint Lawrence Sheet area is drained by creeks which flow directly to the sea.

## STRATIGRAPHY

### Introduction

Metamorphics of possibly Lower Palaeozoic age and younger ultrabasic and other intrusive rocks crop out south of Broad Sound. Farther south the Middle Devonian to Upper Carboniferous Yarrol Basin sequence crops out in the Craigilee Anticline. Fossiliferous Upper Silurian to Lower Devonian sediments and volcanics were mapped in the core of this anticline, unconformably below the Yarrol Basin sequence. Devonian to Carboniferous sediments east of Broad Sound are probably part of the Yarrol Basin sequence. The Devonian-Carboniferous Connors Volcanics crop out within the limits of the Bowen Basin as inliers surrounded by Permian sediments and volcanics.

The Permian-Triassic Bowen Basin sequence occupies most of the area. The base of the sequence consists of the laterally equivalent Lizzie Creek Volcanics and Carmila Beds in the north and the partly equivalent Camboon Andesite and Rannes Beds in the south. The Camboon Andesite and the Rannes Beds probably include pre-Permian rocks. The Back Creek Group, overlying each of these four units, is represented in outcrop mainly by the younger formations; the middle part of the group is present in the north and west, but apparently was not deposited in the southeast. The Rookwood Volcanics are unconformable on the Yarrol Basin sequence and are unconformably overlain by the Boomer Formation of the Back Creek Group. The Blackwater Group, which conformably succeeds the Back Creek Group, is well developed in the west and centre of the area and is overlain by the Mimosa Group.

Marine fossils are present in the Bowen Basin sequence only in the Back Creek Group and in the top beds of the Lizzie Creek Volcanics and Carmila Beds. Four distinct faunas are recognized: Fauna I, in the top part of the Lizzie Creek Volcanics and the Carmila Beds; Fauna II, in the Tiverton Subgroup, the basal part of the Back Creek Group; Fauna III, in the Gebbie Subgroup, the middle part of the Back Creek Group; and Fauna IV, in the Blenheim Subgroup, the top part of the Back Creek Group. These faunas are discussed in Appendix I by J.M. Dickins.

The Lower Cretaceous Styx Coal Measures unconformably overlie Back Creek Group sediments in a small basin southwest of Broad Sound. Relatively thick Tertiary sediments occupy the Duaringa Basin, west of the Mackenzie and Dawson Rivers. Thin Tertiary sediments, commonly lateritized, and basalt and Cretaceous/Tertiary volcanics crop out over much of the area. Cainozoic sediments are widespread in the west.

Ten structural zones are recognized (Fig. 20). The Folded Zone, an elongate zone of tight folding, trends north-northwest across the centre of the area. West of it are the Comet Ridge and the northern end of the Mimosa Syncline. East of the Folded Zone are the Duaringa Basin, the southern end of the Connors Arch, the Strathmuir Synclinorium, the Styx Basin, the Gogango Overfolded Zone, the Marlborough Block, the Craigilee Area, and the Long Island Area. Igneous intrusives occupy only a small part of the area, mainly within the Connors Arch, the Marlborough Block, and the Craigilee area; they represent Carboniferous, Permian, and Cretaceous intrusive episodes.

## Lower Palaeozoic

Metamorphic rocks (Pzl) crop out in a triangular block west of Marlborough homestead, east and southeast of Marlborough, and east of Broad Sound. They are interbedded sediments and volcanics or minor intrusives which have undergone regional metamorphism and subsequent contact and dynamic metamorphism. The topography developed on these rocks is fairly subdued, generally consisting of low rounded hills and rises.

The rock types include quartz-mica schist, talc schist, quartzite, hornfelsed quartz-mica schist, and pyroxenite; some altered volcanics and intrusives also occur.

Bands of hornfelsed coarse quartz-mica schist and knotted schist up to a mile long and 20 or 30 yards wide occur within the serpentinite, about 6 miles southeast of Marlborough. Their trends are visible on the air-photographs, but the bands are too narrow to be shown on the map.

Little is known about the structure of the metamorphics. The outcrops examined are widely separated and bedding is not obvious. The few schistosity directions measured suggest an east to northeast trend.

The interrelationships of the rocks 6 miles southeast of Marlborough indicate that the serpentinite intruded the metamorphics. In most places, however, the contacts between the two are faulted. Near Marlborough homestead, a north-trending fault separates the ultrabasic complex from metamorphics which have a prominent schistosity, striking east and dipping steeply north. Another fault contact is exposed in a highway cutting 2 miles west of Marlborough homestead.

The age of the metamorphics is unknown. Although their stratigraphical relationship was not established, the grade of metamorphism of the rocks, and their complex geological history, suggest that they are older than the Permian rocks to the west. In addition, the east to northeast trend of schistosity is at variance with the north-northwest trend of folding in the Permian Bowen Basin sediments; this schistosity was not produced in the orogeny which folded the Bowen Basin sequence.

Silurian-Devonian volcanics and minor limestone (S-D) are exposed in the core of the Craigilee Anticline and in inliers surrounded by Permian rocks southwest of Old Craigilee homestead. In the Craigilee Anticline, they form a V-shaped belt extending from Redbank and Melrose homesteads in the north to south of Armagh homestead. The volcanics form low hills except east of Hillview homestead and southwest of Craigilee homestead, where the country is rugged. Natural timber cover is generally moderate except about 3 miles east of Hillview homestead where ridges are covered by dense, impenetrable scrub.

Most observed outcrops are of volcanics. Limestone occurs southeast of Melrose homestead and in outcrops north and east of Armagh homestead. Reid (1931) described banded cherts, purplish shale and mudstone, grit, and conglomerate near the Mount Cassidy gold workings.

East of Hillview homestead, the Silurian-Devonian sequence consists dominantly of keratophyre, a tough massive rock, greenish grey to dark grey and glassy. Phenocrysts, where present, are of feldspar (albite to andesine), commonly saussuritized, and are set in an allotriomorphic-granular microcrystalline groundmass in which zeolite, plagioclase, chlorite, calcite, and epidote can be recognized.

West of Melrose homestead, the rocks are mainly spilitic crystal-lithic tuff with minor volcanic conglomerate and chert. The lithic fragments in the tuffs are mainly of fine tuffs and flows, but some are of phyllite. The feldspar crystals are albite-oligoclase, extensively saussuritized. The clasts are set in a tuffaceous matrix consisting of devitrified glass, chlorite, epidote, and calcite.

Rocks collected from the Fitzroy River, west of Craigilee homestead, include crystal-lithic tuff, altered trachyte and spilite, and green andesitic flows and tuffs.

Limestone occurs as the main rock type or as lenses interbedded with volcanics at Armagh homestead and southeast of Melrose homestead. North of Armagh homestead, the limestone is mainly a light-coloured fine-grained poorly bedded to massive rock, closely cleaved but not recrystallized to any extent. Some bands are richly fossiliferous. The limestone is interbedded with volcanics, and large clasts of limestone are included in the volcanics in places.

About 600 yards northeast of Armagh homestead are very fossiliferous thin-bedded to thick-bedded limestone lenses up to 100 feet thick, interbedded with volcanics. The volcanics and associated calcareous tuffaceous sandstone are poorly bedded, red-brown, and contain brachiopods and rare trilobites. This sequence is underlain by poorly exposed massive volcanics.

The limestone southeast of Melrose homestead is thick to thin-bedded, commonly sheared, and recrystallized to marble in part. The thin-bedded limestone is folded and cross-folded in structures involving about 100 feet of section between adjacent anticlinal and synclinal axes; small-scale folds with an amplitude of about 12 inches also affect the bedding.

The volcanics are massive for the most part. Most indications of dip suggest that the unit is essentially an east-dipping wedge. The intense folding in the thin-bedded limestone southeast of Melrose homestead may be only local; thicker-bedded units in this area strike north or northwest and are nearly vertical. The sequence east of Armagh homestead is nearly vertical and strikes northeast. The folding in the Silurian-Devonian rocks antedates the formation of the Craigilee Anticline. East of Armagh homestead, Lower Carboniferous sediments in the east flank of the Craigilee Anticline dip northeast at $70^{o}$, so that their strike is at right angles to that of the Silurian-Devonian rocks, which they overlie unconformably.

The thickness of the Silurian-Devonian sequence is unknown.

Corals collected from the limestone north of Armagh homestead (Du600) are described as Silurian or Lower Devonian (App. 4). The fossils collected farther to the east (Du 228A and B) indicate an Upper Silurian age (App. 7). Corals collected from a limestone near Mount Cassidy were identified as Lower Devonian (Reid, 1931). The Silurian-Devonian rocks are lithologically similar to rocks in the Rockhampton 1:250,000 Sheet area which contain a Lower Devonian coral fauna, and they are regarded as ranging in age from Upper Silurian to Lower Devonian.

## Devonian-Carboniferous

Connors Volcanics (Malone, Jensen, Gregory, & Forbes, 1966)

The Connors Volcanics were included in the Lower Bowen Volcanics when the Saint Lawrence Sheet area was first mapped in 1962 (Malone et al., 1963), but the possibility that some pre-Permian volcanics were involved was discussed. Further mapping in 1964, and age determination results on some intrusions, proved the existence of an older volcanic unit, the Connors Volcanics; the unconformity between the Connors Volcanics and the overlying Carmila Beds and Lizzie Creek Volcanics was recognized in 1964, and the Connors Volcanics were mapped throughout the Duaringa, Saint Lawrence, Mackay, Mount Coolon, and Bowen 1:250,000 Sheet areas.

The type area is along the road from Croydon homestead to Saint Lawrence, as far as the crossing of Big Codling Creek (Grid reference: base, 19391975; top, 20402036) in the Saint Lawrence Sheet area.

In the Duaringa/Saint Lawrence area, the unit crops out in Broadsound Range and farther to the north-northwest, in isolated large and small blocks in the Boomer Range, in a faulted block south of Tooloombah homestead, and in a block surrounded by Lizzie Creek Volcanics near the northern margin of the Saint Lawrence Sheet. The volcanics are resistant to erosion and generally produce moderately dissected rugged highlands.

The Connors Volcanics consist dominantly of massive acid to basic flows, agglomerate, breccia, and tuff. Minor sediments are extensively silicified, jointed, quartz-veined, locally intruded, and contact metamorphosed. Most of the volcanics are extremely altered.

The flows include rhyolite, dacite, trachyte, trachyandesite, andesite, basalt, and spilite. The rhyolite and dacite generally contain phenocrysts of quartz and feldspar set in a fine-grained or cryptocrystalline groundmass. The quartz phenocrysts are partly resorbed; the feldspar phenocrysts and the groundmass are partly replaced by saussurite, sericite, calcite, and clay minerals, the degree of alteration varying from place to place. In places, the dacite contains albite and accessory hornblende and approaches quartz keratophyre.

Trachyte and trachyandesite are not abundant. The trachyte is usually slightly porphyritic. The groundmass is microcrystalline, pilotaxitic, extremely altered, and silicified, and contains minor epidote; it is crossed by thin veinlets of chalcedony. The trachyandesite consists of plagioclase and potash feldspar phenocrysts in a groundmass of small flow-aligned feldspar laths; epidote has partly replaced the plagioclase phenocrysts.

Andesite is probably the most common flow rock. It is a fine to coarse-grained massive or porphyritic rock, weakly flow-banded in places. The phenocrysts are mostly plagioclase, partly altered to epidote and calcite; others are hornblende, potash feldspar, and rare augite and quartz. The groundmass consists of feldspar laths, calcite, epidote, chlorite, and clay minerals. Quartz-epidote veins a few feet long are common; they are generally less than an inch wide, but are up to 6 inches wide in places.

Basalt is abundant in places. It is generally porphyritic to glomeroporphyritic, and contains phenocrysts of augite and plagioclase in an intersertal or intergranular groundmass. In some flows, amygdales of chalcedony and chlorite are common and the rock is cut by thin siliceous veins. Alteration products, commonly after augite and the other mafic minerals, include bastite, chlorite, calcite, and clay minerals. Some of these extremely altered basic flows are possibly spilites; in outcrop some of them display possible pillow structures. Others are so altered as to be unidentifiable.

Thick beds of massive light grey, green, green and purple, and dark-coloured agglomerate are characteristic of the Connors Volcanics. They are dominantly andesitic, dacitic, or rhyolitic, and are extremely altered; some are sheared and many have been diagenetically altered. Fragments range from less than 1 inch to 6 feet in diameter and commonly merge into the matrix; they are either of a single lava or are a mixture of extrusives and pyroclastics. The groundmass is massive or porphyritic. Variants from the usual thick-bedded agglomerate are: alternating thin beds of fine and coarse agglomerate; thin interbeds of fine agglomerate with other volcanics; and an association with volcanic breccia. One outcrop, consisting of blocks of flow-banded trachyte in a fine-grained, probably trachytic matrix is probably an autobreccia. Elsewhere, volcanic breccia contains rafted blocks up to 8 feet across.

Vitric, lithic, and crystal tuff probably constitute more than one-third of the unit, but in many places the rocks are so silicified that they can be mistaken for porphyritic flow rocks in outcrop. The tuffs contain alteration products similar to those found in the flow rocks; most have undergone some diagenetic recrystallization, and the glassy groundmass and fragments of the vitric tuff are devitrified. The tuffs are mainly rhyolitic, dacitic, or andesitic, and the lithic fragments consist of volcanic material of those compositions. Much of the tuff is sheared and many lithic fragments are flattened and distorted; crystal fragments are broken or deeply embayed. Flow texture is present in the groundmass of some beds of crystal lithic tuff.

Volcanolithic sandstone, tuffaceous sandstone, and volcanic conglomerate are present. There has been some contact metamorphism close to intrusions, but the effects are usually obscured by widespread silicification. However, in one place, epidosite was produced, probably from a calcareous sandstone.

Poor bedding is a characteristic of the Connors Volcanics and consequently the structure is difficult to determine. Dips are mainly to the east, at angles between $20^{o}$ and $60^{o}$; and the formation was probably laid down as a wedge, within which the various volcanic rock types lens out along strike, suggesting supply from many volcanic foci. There is no evidence of folding of the unit as a whole, and in places it appears to have protected Permian rocks overlying it to the west from the effects of the post-Permian folding. Possibly the present easterly dip of the Connors Volcanics is partly depositional, modified by faulting and block uplift and rotation that produced steeper easterly dips during compression from the east and northeast.

Joints and faults are common and in places are occupied by quartz veins. It is impossible to determine the amount of movement on most of these fractures because of the lack of marker beds.

The base of the Connors Volcanics is not exposed. They are unconformably overlain by the Carmila Beds, the Lizzie Creek Volcanics, and the Back Creek Group, though the unconformity is rarely exposed. Its existence is indicated by the marked divergence between the structures in the Connors Volcanics and those in the overlying Lower Permian units, and has been confirmed by the age determination results.

The lateral relationships of the Connors Volcanics are not known. Their lithology and structural and stratigraphical position suggest equivalence to the Silurian-Devonian rocks. In the Mackay Sheet area, the Connors Volcanics are thought to be equivalent in part to the Campwyn Beds of Devonian to Carboniferous age. Possibly, the Connors Volcanics as mapped include rocks of different ages. They are intruded by Carboniferous granite.

The lack of bedded sediments and the predominance of flows and unbedded pyroclastics suggest that the Connors Volcanics were deposited subaerially. Their thickness is unknown, mainly because of poor bedding. The consistent easterly dips east of Markwell homestead suggest that the unit may be very thick, but fractures are so common that faulted repetitions of section are likely.

Undifferentiated Devonian-Carboniferous

Rocks of Devonian and Carboniferous age occur in two blocks in the northeast of the Duaringa Sheet area and on Long Island in the northeast of the Saint Lawrence Sheet area.



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The smaller block in the Duaringa Sheet area is 5 miles west of Redbank homestead. It is bounded on the northeast and southeast by faults, and the rocks are unconformably overlain by the Rookwood Volcanics. The basal part of the section consists of green basic tuff, lapilli tuff, flows, and volcanic conglomerate. The upper part consists dominantly of greenish grey siltstone with thin interbeds of sandstone, oolitic limestone, and green tuff. Corals collected from the basal tuff are of Upper Devonian age; the limestone contains Lower Carboniferous corals.

A larger block was mapped 8 miles northwest of Redbank homestead. In this area, the rocks are dominantly green basic volcanics (tuff, lapilli tuff, and flows) with minor tuffaceous sandstone and siltstone. Fossils have not been found in this block; the rocks are probably mainly Upper Devonian, but may include some Silurian-Devonian volcanics.

The Devonian-Carboniferous rocks in the Duaringa Sheet area are unconformably overlain by the Rookwood Volcanics. Devonian to Lower Carboniferous volcanics and tuffaceous sediments also crop out on Long Island, where they are overlain by Lower Carboniferous sediments.

Lower Carboniferous

The main outcrops of Lower Carboniferous sediments are in the flanks of the Craigilee Anticline; small outcrops occur on Long Island. In the Duaringa Sheet area, the lower, dominantly silty part of the sequence forms low bare hills; the upper part produces strike ridges with slightly more relief. Limestone beds support dense scrub.

The dominant rock in the lower part of the sequence is dark grey to greenish grey siltstone. Some of the siltstone is fissile, but most of it is tough and indurated, and commonly has a cherty appearance. Thin, commonly graded beds of fine to medium-grained sandstone are finely interbedded with the siltstone.

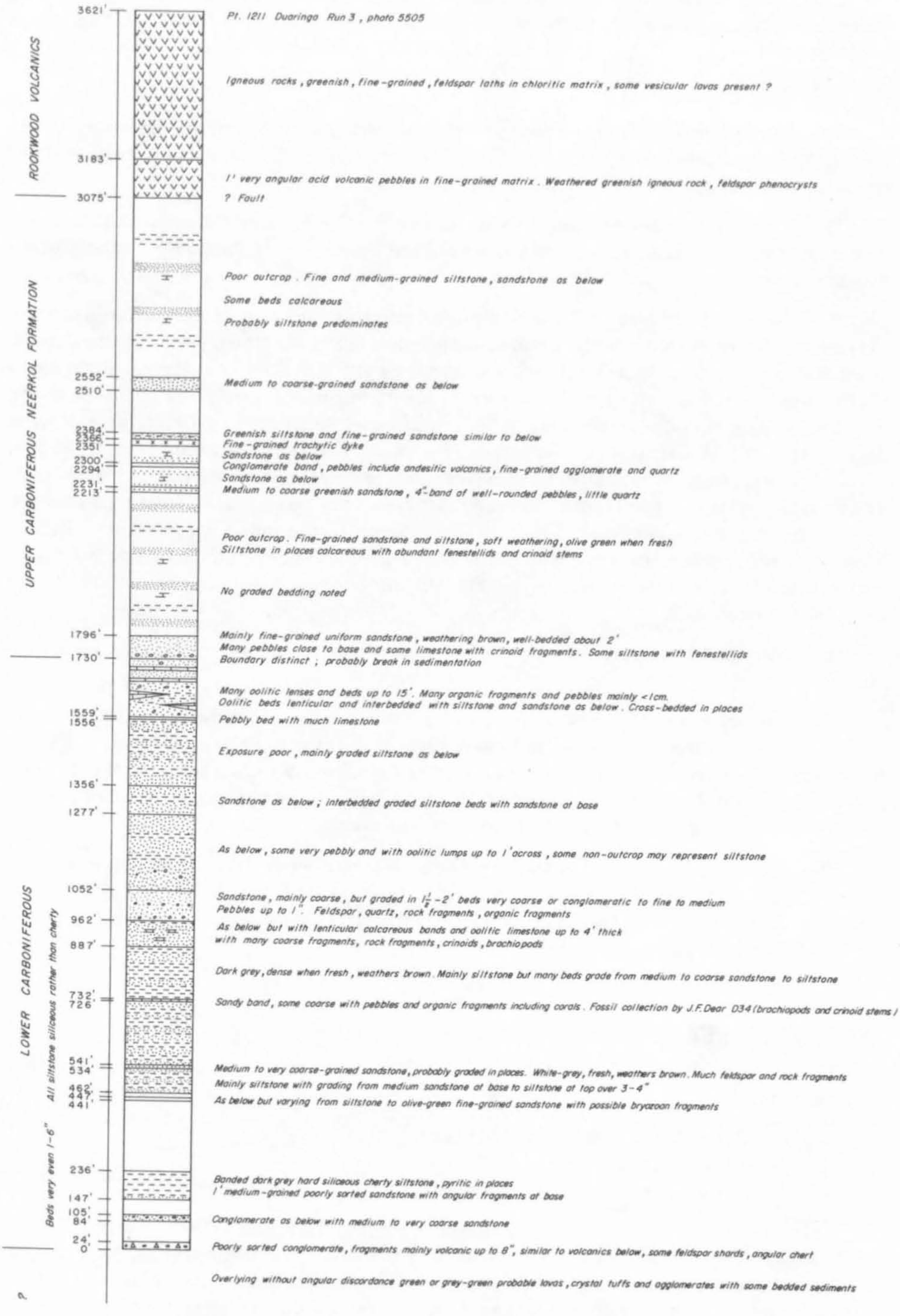
Oolitic limestone, the characteristic rock of the upper part of the sequence, occurs as beds up to 20 feet thick. A persistent bed occurs in the middle part of the succession on the eastern flank of the Craigilee Anticline. A partly oolitic, partly crinoidal cross-stratified limestone with many lithic clasts occurs at the top of the unit on the east flank. Both these limestone beds are less well developed in the sequence on the west flank (Fig. 3). The limestone consists of oolites (40-60 percent of rock) set in a matrix of finely granular calcite. The cores of the oolites are mostly grains of vitric tuff, feldspar, quartz, and organic material.

Sandstone is common, mainly in the upper part of the unit. It is mostly greenish grey, medium to coarse-grained, and contains beds of granule and pebble conglomerate. The sandstone consists mainly of feldspar and lithic grains. The pebbles are mainly of light-coloured cherty vitric tuff. Some sandstone beds are calcareous and contain oolite grains.

The Lower Carboniferous sediments unconformably overlie the Silurian to Devonian rocks. Considerable variation in the thickness of the unit suggests onlap on to a ridge of Silurian-Devonian rocks. North of Craigilee homestead about 3500 feet of siltstone is present between the lowest oolitic limestone and the Silurian-Devonian strata, but south of Craigilee homestead the oolitic limestone rests directly on the Silurian-Devonian rocks. The Lower Carboniferous rocks are disconformably overlain by the Neerkol Formation.

The maximum thickness of the Lower Carboniferous sequence on the east flank of the Craigilee Anticline is 7000 feet; on the west flank it is 1730 feet (Fig. 3).

The unit is only sparsely fossiliferous in the Duaringa Sheet area. The lower part contains brachiopods of Upper Tournaisian age (App. 3). Corals are rare in the limestones, but species of *Lithostrotion*, *Syringopora*, and *Symplectophyllum* have been collected (App. 4); these are of probable Viséan age.




*Measured by J.M. Dickins (B.M.R.) and J.F. Dear (G.S.Q.) using pace and compass.*

Figure 3 Measured section, Carboniferous sequence, Yarrol Basin.

The Lower Carboniferous sediments on Long Island include coralline and oolitic limestones. The sequence is here about 1200 feet thick and overlain by Upper Carboniferous sediments.

Neerkol Formation (Reid, 1930).

The name Neerkol Series (Reid, 1930) was changed to Neerkol Formation by Hill (1953). The formation crops out in the Craigilee Anticline in the Duaringa Sheet area, and on Long, Barren, and South Barren Islands in the Saint Lawrence Sheet area.

The formation underlies low lightly timbered hills on both flanks of the Craigilee Anticline. Bedding trends are not as obvious as in the upper part of the Lower Carboniferous sequence.

The Neerkol Formation in the Craigilee Anticline consists of grey siltstone, fine-grained sandstone with minor limestone, and conglomerate. Siltstone is the dominant rock, constituting more than 80 percent of the section; locally it grades into fine-grained sandstone. Most of the siltstone is blue-grey to black, hard, and poorly bedded to massive. Fossils are sparsely distributed except for a few bands. Much of the siltstone in the lower part of the unit is calcareous. Sandstone is present mainly in the lower part of the formation. It is greenish grey, fine to medium-grained, poorly bedded to massive, and slightly calcareous in places. It weathers brown. Sandstone at the base contains scattered pebbles. Thin crinoidal limestone and coquinite beds occur in the lower part of the formation. Thin beds of conglomerate and medium to coarse-grained feldspathic and lithic sandstone occur throughout the section. The pebbles in the conglomerate consist mainly of light grey cherty vitric tuff.

On Long Island, the Neerkol Formation consists of sandstone, siltstone, and conglomerate.

The Neerkol Formation disconformably overlies the Lower Carboniferous sediments. The evidence for disconformity is the sharp lithological change between the two units, and the marked differences between their faunas. The formation is unconformably overlain and overlapped by the Rookwood Volcanics on the west flank of the Craigilee Anticline, and by the Youlambie Conglomerate south of Armagh homestead.

The maximum estimated thickness of the Neerkol Formation is 10,000 feet in the eastern limb of the Craigilee Anticline; in the western limb it is 5000 feet, and on Long Island it is at least 7000 feet thick. Richly fossiliferous beds occur throughout (App. 3); the fossils indicate an Upper Carboniferous age.

## Permian

Nomenclature of the Bowen Basin Succession

The geological map of Queensland (Hill, 1953) summarized the then current nomenclature as follows:

Upper Bowen Coal Measures (youngest)
Middle Bowen Group
Lower Bowen Volcanics (oldest)

Essentially, this followed the subdivision proposed by Jack (1879) and modified by Reid (1929). This nomenclature was adopted in the early part of the regional mapping of the Bowen Basin, except that the term Middle Bowen Beds was used instead of Middle Bowen Group. As the regional mapping of the Bowen Basin and its environs progressed the subdivision was expanded to accommodate new stratigraphic units not previously recognized, and the status of the former subdivisions was revised.

The Lower Bowen Volcanics, the basal unit of the former subdivision, cannot be traced as a rock unit throughout the basin. The basal part of the Bowen Basin succession consists of four more or less synchronous rock units which differ in gross lithology and were deposited in different, largely separate parts of the basin. The four units are: the Reids Dome Beds, the Camboon Andesite, the Carmila Beds, and the Lizzie Creek Volcanics. The Lizzie Creek Volcanics (new name) is the original Lower Bowen Volcanics of the northern Bowen Basin and is defined in this Report. The Carmila Beds, which crop out in the east of the Duaringa and Saint Lawrence Sheet areas, are defined by Jensen, Gregory, & Forbes (1966). The Camboon Andesite, tentatively recognized in the southeast of the Duaringa Sheet area, was first recognized in the Mundubbera Sheet area (Derrington, Glover, & Morgan, 1959). The Reids Dome Beds are not present in this area.

The Middle Bowen Group can be recognized throughout the Bowen Basin. Despite local variations, the gross lithology of the group is very consistent throughout the basin. The formal name Back Creek Group was first applied to this unit by Derrington et al. (op.cit.), who nominated a type area in the Mundubbera 1:250,000 Sheet area.

In this Report the name Back Creek Group is applied to the former Middle Bowen Group throughout the Bowen Basin.

The Upper Bowen Coal Measures are also a valid unit of group rank which can be recognized throughout the Bowen Basin. However, the coal seams are mainly confined to one formation (except in the northern part of the basin), and the term coal measures is not appropriate for the whole group. In this Report, a new name Blackwater Group is defined and used in place of 'Upper Bowen Coal Measures'.

The Triassic units of the Bowen Basin have been previously mapped as separate formations. In this Report they are grouped in the Mimosa Group (new name defined here), because they represent essentially continuous sedimentation in a single depositional province.

Camboon Andesite (?) (Derrington, Glover, & Morgan, 1959)

Volcanic rocks crop out in three areas near Thuriba homestead in the southeast of the Duaringa Sheet area. Their age is not known and their relationships are obscured by the structural complexity of the area. They were first mapped as Mesozoic volcanics (Malone et al., 1963) but more detailed mapping (Olgers et al., 1964) revealed that they are exposed beneath the Rannes Beds in the cores of small anticlines, and they were mapped as Lower Permian Camboon Andesite.

The Camboon Andesite was named after Camboon homestead on the Mundubbera Sheet area (Derrington et al., 1959). The topography on the formation in the Duaringa Sheet area ranges from gently undulating hilly terrain to rugged hills. The vegetation is generally sparse, giving rise to a reasonably distinctive, light-toned air-photo pattern; however, in many places, the clearing of timber has made the interpretation of boundaries difficult.

The Camboon Andesite consists of andesitic flows, agglomerate and breccia, crystal tuff, crystal lithic tuff, and volcanic conglomerate. The flows are generally massive fine-grained greenish grey to dark grey andesite; some are porphyritic. Massive dark grey agglomerate, containing boulders up to a foot in diameter, occurs east and southeast of the homestead near the top of the unit.

The Camboon Andesite crops out in the cores of two anticlines and, except in the west limb of the Thuriba Anticline, the formation is overlain, possibly conformably, by the Rannes Beds. In the west limb of the Thuriba Anticline, the Camboon Andesite is overlain by the Oxtrack Formation. The relationship between the Camboon Andesite and Oxtrack Formation is not clear in the field, mainly because of poor outcrop. To the south, in the Mundubbera Sheet area, the unit is disconformably overlain by the Oxtrack Formation in places and by the Lower Permian Buffel Formation elsewhere (Jensen, Gregory, & Forbes, 1964). The base of the Camboon Andesite is not exposed and the thickness is not known.

Rannes Beds (Dunstan, 1901a)

The name 'Rannes Altered Rocks' was first used by Dunstan (1901a) to describe the slaty rocks in the Rannes Hill area, 34 miles southeast of Duaringa in the Monto Sheet area. Dunstan included these rocks in the 'Gympie Formation'. Reid & Morton (1928) used the name 'Rannes Series' for the rocks in the Gogango Range and correlated them with the Lower Palaeozoic 'Emu Park and Anakie Series'. Olgers et al. (1964) subdivided the rocks in the Gogango Range into two units: an older unit, the Rannes Beds, consisting predominantly of slaty rocks, and the Back Creek Group mainly of interbedded arenite and siltstone. This twofold subdivision in the Gogango Range has been retained on the accompanying geological map. The Rannes Beds have since been recognized in a continuous belt up to 11 miles wide extending from Goovigen in the Monto Sheet area to near Marlborough in the southeast of the Saint Lawrence Sheet area, a distance of about 100 miles.

Many creeks have deeply incised the Rannes Beds, producing a characteristic dendritic photo-pattern. The vegetation is generally moderately dense and includes brigalow scrub in places. The combination of steep-sided closely spaced drainage and dense scrub makes access to much of the area underlain by the Rannes Beds very difficult.

The Rannes Beds consist dominantly of mudstone and argillaceous labile arenite; conglomerate, limestone, volcanics, and sediments derived from volcanic rocks occur in places. Most rocks are sheared, foliated, and slightly recrystallized as a result of low grade regional and dynamic metamorphism.

The arenites are mainly very fine to medium-grained light grey to greenish rocks containing 10-50 percent largely recrystallized argillaceous matrix. Lithic clasts and quartz grains are generally equally abundant. Rounded, broken, and embayed crystals of feldspar are abundant in some specimens; the feldspar crystals and some lithic clasts were apparently derived by reworking of pyroclastics, but most of the clastic material was derived by erosion of granitic and metamorphic rocks. The arenites are in places thinly interbedded with mica schist and sericite schist. The schist bands are the result of recrystallization of mudstone layers. The arenites are recrystallized, their matrix is replaced, and one or more foliations are developed; porphyroblasts of muscovite and chlorite have grown in some arenites.

The finer sediments include foliated mudstone, slate, phyllite, and schist. They are grey, green, buff, or yellow, and commonly split readily along the foliation in weathered outcrop. A second foliation in some of the mica phyllite has produced chevron folding of the first.

Lenses of volcanics are included in the Rannes Beds east and southeast of Balcomba homestead, west of Grantleigh Siding, and in the southern Gogango Range in the Duaringa, Rockhampton, and Monto Sheet areas. Near Balcomba homestead, the volcanics consist of volcanic breccia, silicified rhyolite, andesite, and silicified sheared trachyte. West of Grantleigh Siding, the volcanics are mainly foliated recrystallized lithic and crystal tuffs; they are grey, green, or purple very fine to medium-grained rocks and are uneven-grained and pebbly in places. Lustrous purple chlorite schist occurs in the volcanics, apparently produced by strong shearing of very fine-grained crystal-lithic tuff. Among the associated rock types in this area are foliated and recrystallized arenites, produced by regional metamorphism of feldspathic-lithic arenite and arkose derived by reworking of pyroclastics, and volcanic conglomerate and andesitic agglomerate.

In the southern Gogango Range, the volcanics include altered basalt, similar to rocks in the underlying Camboon Andesite, and porphyritic rhyolite, as well as tuffs and tuffaceous sediments. These rocks also are foliated and partly recrystallized. Quartz lithic and volcanic-pebble conglomerates are also present in this area.

Calcareous sediments are common only in the southern Gogango Range, particularly in the Rockhampton and Monto Sheet areas. They include pinkish grey sheared and recrystallized crinoidal calcarenite containing large calcite crystals up to 5 mm across; foliated fine-grained partly recrystallized pebbly limestone containing flattened, aligned volcanic pebbles up to 4 cm across; and fossiliferous red and grey limestone, partly recrystallized to marble and interbedded with volcanics and tuffaceous sediments.

Foliation is widespread in the Rannes Beds and occurs at widely varying angles to the bedding. Two foliation directions in the one rock are not common, but are present in a number of outcrops. Jointing and quartz veining are common throughout the unit, particularly west of Rookwood homestead. In this area, some of the rocks have been both contact metamorphosed and regionally metamorphosed. They include hornfelsed arenite consisting of quartz, feldspar, and lithic grains, some of which are recrystallized, set in a hornfelsed quartz-feldspar matrix. They were possibly metamorphosed by a granodiorite intrusion which crops out about 2 miles to the east; the intervening area is occupied by Cainozoic sediments.

The Rannes Beds are the most intensely deformed unit in the area; they consist of tightly folded argillaceous sediments which show either slaty or fracture cleavage. The more competent sandy beds are jointed normal to the bedding. The cleavage generally dips steeply to the east, suggesting that most of the tight folds are overturned to the west (Pl. 1, fig. 1). Small normal faults and thrust faults (Pl. 1, fig. 2) are common throughout the unit. Quartz veining is commonly associated with the faulting.

The relationships between the Rannes Beds and the underlying and overlying units were difficult to establish because of poor outcrop and extensive faulting and shearing along boundaries.

At Thuriba homestead in the southeast, the Rannes Beds apparently conformably overlie the Camboon Andesite, and at Rookwood Outstation they overlie the Connors Volcanics. The boundary between the Rannes Beds and Camboon Andesite is transitional. The flows of the Camboon Andesite grade upwards into the argillites of the Rannes Beds through an intermediate sequence of crystal tuff and tuffaceous sediments.

Along the western edge of their outcrop belt, from Thuriba homestead in the south to the Marlborough area in the north, the Rannes Beds are unconformably overlain by the Boomer Formation. The unconformity has been clearly observed in only one area, 8 miles north-northeast of Balcomba homestead, where the Boomer Formation dips at $10^{o}$ to the west and overlies the steeply east-dipping Rannes Beds.

The eastern margin of the Rannes Beds outcrop belt is in many places normally faulted and thrust-faulted. Along this margin, the formation is unconformably overlain by the Lower Permian Youlambie Conglomerate, and the Upper Permian Rookwood Volcanics and Boomer Formation.

The age of the Rannes Beds is not known. The rocks of the Gogango Range, consisting mainly of Rannes Beds, were regarded as Permo-Carboniferous by Dunstan (1901), and Lower Palaeozoic by Reid & Morton (1928). Hill (1951) stated that they could possibly be metamorphosed Permian rocks, but were more likely to be Lower Palaeozoic or older, and form a structural high (Gogango High) between the Yarrol Basin to the east and the Bowen Basin to the west. Malone et al. (1963) mapped parts of the range as Silurian-Devonian, undifferentiated Palaeozoic, Permian, and Mesozoic, and Olgers et al. (1964) regarded the Gogango Range as consisting largely of Permian rocks, with some Silurian-Devonian at Thuriba homestead.

The only fossil collections made from the Rannes Beds are from the Thuriba homestead area (collections 146 and 1614). Hill (in App. to Malone et al., 1963) after examining the collection from locality 146, suggested that the limestone was probably of Silurian or

Devonian age. The limestone is highly sheared and contains fragments of corals only. Additional fossils collected from the area in 1964 (locality 1614) indicate that the age of the rocks at Thuriba is probably Upper Palaeozoic rather than Lower Palaeozoic (Hill, pers. comm.). Fossils have been found in the Rannes Beds at three other localities in this area: wood fragments in a road cutting along the Capricorn High 3 miles southeast of Edungalba, a single specimen of Eurydesma 5.5 miles east-northeast of Balcomba homestead (Du 188), and some plant material 2 miles north of Rookwood outstation. Crinoidal limestone is interbedded with slate in the Gogango Range on the Rockhampton Sheet area. The available fossils are inadequate to determine the age of the Rannes Beds. The plants indicate a post-Devonian age and the specimen of Eurydesma indicates a Lower Permian age. The crinoid stem joints in the limestone in the Rockhampton Sheet area are less than 1/8 inch in diameter, much smaller than crinoidal material occurring in Permian rocks (J.M. Dickins, pers. comm.).

The Rannes Beds are thought to be at least partly Lower Permian, though they may include some older rocks. The magnitude of the angular unconformity between the Upper Permian Boomer Formation and the Rannes Beds near Balcomba homestead suggests that the Rannes Beds in this area may be pre-Permian. The unit is possibly equivalent in part to the Camboon Andesite. The thickness of the Rannes Beds is not known because of the intense deformation, but it is thought to be of the order of several thousand feet.

Youlambie Conglomerate (Dear, McKellar, & Tucker, in prep.)

The Youlambie Conglomerate has been traced from the type area in the Monto Sheet area, through the Rockhampton Sheet, to the Duaringa Sheet area, where it crops out in a northwesterly belt south of Armagh homestead. An isolated small area of poor outcrop occurs 15 miles to the northwest. The unit forms lightly timbered rounded hills, and, in places, strike ridges. It gives rise to much greater relief than do the adjacent units, and is mostly well exposed.

Conglomerate, though not dominant, is characteristic of the unit. In the Rockhampton Sheet area, conglomerate lenses are up to several hundred feet thick, and are characterized by cobbles and boulders of granitic rocks. However, in the Duaringa Sheet area conglomerate beds are thin and granitic constituents are rare. The pebbles and cobbles are rounded and consist of acid, crystal, and vitric tuff and porphyry, set in a sandy or silty matrix.

The sandstone is grey, very tough, mostly fine to medium-grained, rarely coarse-grained, and contains scattered pebbles. The clasts are mainly lithic grains and feldspar; some of the sandstone is very feldspathic. The siltstone is generally greenish grey, tough, silicified, and cherty in appearance; in places it is soft, fissile, dark grey, and contains plants.

South of Armagh homestead, the Youlambie Conglomerate dips generally to the south off an east-trending ridge of Silurian-Devonian and Upper Carboniferous rocks. The Carboniferous sediments between the Silurian-Devonian volcanics and the Youlambie Conglomerate wedge out in places in this small area, because of progressive onlap of younger units on to the Silurian-Devonian high. On a regional scale the Youlambie Conglomerate unconformably overlies the Neerkol Formation, the Lower Carboniferous sediments, and the Silurian-Devonian rocks.

Northwest of Armagh homestead, the Youlambie Conglomerate unconformably overlies the Rannes Beds. In the western part of the Rockhampton Sheet area the unit is about 3000 feet thick, and a similar thickness is assumed in the Duaringa Sheet area; it cannot be estimated accurately because of considerable strike faulting. Plants collected from the unit have been determined by White (App. 2) as Noeggerathiopsis hislopi of the type present in Lower Permian Beds. East of the eastern boundary of the Duaringa Sheet, a sparse poorly preserved brachiopod fauna of probable Lower Permian age was collected from the top of the unit.

## Lower Permian of Quail Island

Quail Island is underlain by at least 15,000 feet of Lower Permian siltstone, containing ferruginous concretional feldspathic sandstone and lithic conglomerate. The sequence overlies the Neerkol Formation. Lower Permian sediments have tentatively been mapped south of Quail Island on the mainland, where they appear to be faulted against Lower Palaeozoic metamorphics. The Lower Permian rocks of Quail Island can possibly be correlated with the Youlambie Conglomerate of the eastern Duaringa Sheet area.

## Lizzie Creek Volcanics

Lizzie Creek Volcanics is a formal name introduced in this Report to replace the informal 'Lower Bowen Volcanics' (Jack, in Jack & Etheridge, 1892). The unit includes the volcanics to which the name 'Lower Bowen' was originally applied, but not all the volcanics subsequently grouped under this name.

The name is derived from Lizzie Creek, in the Mount Coolon Sheet area. The type section is from Hazlewood Creek near the junction with Lizzie Creek, along Lizzie Creek and the Lizzie Creek road, and continuing northeast to the contact with the underlying Devonian-Carboniferous Connors Volcanics (Grid reference: base, 67023565; top, 66263500) in the Mount Coolon 1:250,000 Sheet area (Malone, in prep.).

The top of the Lizzie Creek Volcanics and the transition to the overlying Tiverton Subgroup are completely exposed in Hazlewood Creek, 8 miles southeast of the type section.

The Lizzie Creek Volcanics occupy a belt trending north-northwest from the Broadsound Range in the Saint Lawrence Sheet area to north of Collinsville in the Bowen Sheet area, and isolated blocks east of the Broken River Range in the Mackay and Proserpine Sheet areas.

Rock types include: andesite, dacite, rhyolite, trachyte, and basalt flows, tuff, agglomerate, and breccia; sublabile, labile, volcanic, and tuffaceous sandstones, greywacke, siltstone, dark argillite, and ashstone; pebble, cobble and boulder conglomerate and volcanic conglomerate; fossiliferous limestone, calcareous lithic sandstone, and calcareous tuff.

The thickness is about 12,000 feet in one section southeast of Collinsville. The thickness in the type section is difficult to estimate because of minor folding; it is of the order of 10,000 feet.

The Lizzie Creek Volcanics contain fossil wood and plants including *Glossopteris*, *Noeggerathiopsis*, *Samaropsis*, and *Cordaites*. At many localities a marine macrofauna had been found near the top. The fossils belong to Fauna 1 (Dickins et al., 1964) and include *Eurydesma hobartense*, *Deltopecten limaeformis*, *Pachymyonia* cf. *etheridgei*, *Aviculopecten* sp., *Chaenomya* sp., *Merismopteria* sp., *Notospirifer* sp., *Ingelarella* sp., and *Warthia* sp.

The marine fossils indicate a Lower Permian age, approximately basal Artinskian; deposition began much earlier, but probably during the Lower Permian. West of Collinsville, the Lizzie Creek Volcanics are unconformable on Upper Carboniferous intrusives which have given isotopic ages of about 285 million years (A.W. Webb, pers. comm.).

The Lizzie Creek Volcanics are conformably and transitionally overlain by the Tiverton Subgroup of the Back Creek Group in Hazlewood Creek. Farther north, the Gebbie Subgroup is regionally disconformable or unconformable on the Lizzie Creek Volcanics. The Lizzie Creek Volcanics and the Carmila Beds are lateral equivalents and are in contact on the Connors Range. They are distinguished because the Lizzie Creek Volcanics are dominantly andesitic and the volcanics of the Carmila Beds are mainly acidic.

The Lizzie Creek Volcanics are unconformable on the Connors Volcanics, though the actual contact has not been seen; the existence of the unconformity is based on regional mapping data and is confirmed by age determinations.

In the Saint Lawrence Sheet area, the Lizzie Creek Volcanics crop out in the Connors Range near the northern Sheet boundary, and in a narrow belt to the west of the range extending southeast nearly to Yatton homestead. The unit generally produces rugged to moderately subdued topography; some upland valleys have formed on the unit within the Connors Range.

The Volcanics consist dominantly of andesitic volcanics, slightly less abundant rhyolitic and dacitic volcanics, some basalt, and minor sediments. The andesite flows are fine to coarse-grained, approaching microdiorite in some outcrops, are rarely banded, and are porphyritic in places. When fresh, they are green, dark green, blue-green, and rarely yellow-brown, but most outcrops are deeply weathered and consist mainly of secondary calcite, epidote, chlorite, and clay minerals. Andesitic pyroclastics are more common than flows and include lithic tuffs containing rounded fragments of andesite, crystal-lapilli tuffs with fragments up to 1 inch across, agglomerate, and autobreccia. Most of the andesitic pyroclastics are green, or mottled purple and green, and deeply weathered.

The acid volcanics consist of rhyolite and dacite flows and some crystal tuffs. The flows are buff, pale green, green, and purple porphyritic rocks exhibiting flow textures; in some outcrops they show signs of turbulent flow. Rounded and resorbed quartz phenocrysts and less resorbed subhedral to euhedral feldspar phenocrysts, somewhat altered to saussurite and clay minerals, are set in a fine to very fine-grained or cryptocrystalline groundmass of quartz, feldspar, devitrified glass, and alteration products including clay minerals and chlorite. The tuffs are crystal and crystal-lithic tuffs containing phenocrysts of quartz and feldspar and lithic fragments up to 1/2 inch across. Some contain large euhedral to subhedral crystals of potash feldspar and plagioclase, both partly altered, in a mass of fine-grained quartz, chlorite, and clay minerals, displaying a eutaxitic texture. Others are very finely laminated and appear to consist of thin siliceous vitric tuff bands, welded together and devitrified. In one outcrop, a sill of microgranite appears to be interbedded with acid volcanics.

The basalt flows are porphyritic, containing phenocrysts of plagioclase and, in places, augite. The mafic minerals are extensively altered to chlorite and calcite and the feldspar is partly saussuritized. Flow textures are present in places.

Sediments in the Lizzie Creek Volcanics are neither abundant nor well exposed in this area. They include conglomerate, consisting of granules, pebbles, and cobbles of volcanics in a reworked tuffaceous matrix, interbedded with reworked tuff and lithic sandstone which contains some pebbles. The matrix is green and andesitic in some places, and a buff dacitic crystal tuff in others. The lithic sandstone is medium to coarse-grained, well bedded and cross-bedded, and contains fragmented feldspar crystals, angular lithic grains, and rounded glassy quartz grains. Calcareous siltstone, calcareous tuffaceous sandstone, and a few beds of limestone near the top of the unit crop out near Collaroy homestead and farther west near the contact with the Back Creek Group; these calcareous sediments are rich in marine fossils.

The volcanic conglomerate and lithic sandstone are obviously derived from an acid volcanic terrain; they are very similar to sediments in the Carmila Beds. The Lizzie Creek Volcanics in the Connors Range consist of about equal parts of andesitic and acid volcanics and sediments derived from volcanics. In this area the unit merges laterally into the dominantly acid volcanics and associated sediments of the Carmila Beds.

In the Saint Lawrence Sheet area, the Lizzie Creek Volcanics are unconformable on the Connors Volcanics and parts of the Urannah Complex. The unconformity is fairly clearly indicated near the northern margin of the Sheet area, where a block of Connors Volcanics, dipping east at $30^{o}$ to $60^{o}$, is overlain to the west by Lizzie Creek Volcanics dipping to the southwest; unfortunately, exposures are poor near the contact.

The boundary between the Lizzie Creek Volcanics and the Carmila Beds is an arbitrary line separating the dominantly andesitic volcanics of the former from the dominantly acid volcanics of the latter. In general, the transitional zone, where there are as much andesitic as acid volcanics (as in the Connors Range), was placed in the Lizzie Creek Volcanics. In one place, at the boundary between the two units, acid volcanics transitionally overlie andesitic volcanics; elsewhere, the andesitic volcanics are on top. The two units are at least partly lateral equivalents: the upper parts of both include fossiliferous calcareous marine sediments containing similar faunas.

The Back Creek Group overlies the Lizzie Creek Volcanics with apparent conformity. In places, it overlaps the Lizzie Creek Volcanics and overlies the Connors Volcanics.

Bedding is reasonably well developed. In the west, the unit dips to the southwest. In the Connors Range it is folded into fairly broad structures; these reflect deposition on an irregular basement of Connors Volcanics and Urannah Complex, and are somewhat modified by tectonic folding. Near Collaroy homestead, the Lizzie Creek Volcanics are folded into a broad syncline, with flank dips of $15^{o}$ to $30^{o}$ and a shallow south plunge. A broad mature upland valley is situated in its trough.

The Lizzie Creek Volcanics contain a proportion of subaerial volcanics, but the wide distribution and good bedding of sediments and the abundance of reworked volcanics suggest deposition in a dominantly aqueous environment. The presence of marine fossils indicates that the upper part of the unit is marine; the rock types suggest deposition close to active terrestrial volcanoes. No conclusive evidence of submarine extrusive activity was seen.

The formation seems to be thinner in this area than in the type area to the north, but the thickness is hard to estimate. The wide distribution of the upper part, the shallow dips, and the number of inliers of Connors Volcanics and Urannah Complex suggest that it is only a thin veneer in the Connors Range.

Marine fossils were collected at four localities (SL199, SL22, SL59, and SL60) in the Lizzie Creek Volcanics. The fossils (App. 1) are Lower Permian, approximately basal Artinskian, and as they occur near the top set an upper age limit. It is probably entirely Lower Permian.

Carmila Beds

The Carmila Beds crop out on and east of the Connors Range; in a large area north of Marlborough; on both sides and around the southern end of the Broadsound Range; and in a small area southeast of Apis Creek. The topography reflects the varied lithology and structure. In the Connors Range the Beds occupy shallow depositional basins and generally have a subdued topography. At the eastern edge of this range and farther east, easterly dipping beds produce prominent cuestas and strike ridges. A similar topography is present where the Beds crop out around the Broadsound Range and southeast of Apis Creek homestead. Here, however, the dips are steeper and strike ridges of moderate relief predominate. The area north of Marlborough is a mass of moderately rugged hills rising to 1700 feet above the surrounding coastal plains. Strike ridges are common in the northwest of the block, but elsewhere the topography does not reflect structure. The most rugged topography is in the east where contact-metamorphosed rocks rise steeply above the area of low relief underlain by intrusive rocks.

The Carmila Beds in the northern part of the Saint Lawrence Sheet area, as in the type area, consist of three parts: (1) a lower sequence of acid volcanics and minor andesitic volcanics and volcanic conglomerate; (2) a middle sequence of volcanic conglomerate and minor volcanolithic sediments with thick beds of mainly acid volcanics producing prominent cuestas; and (3) an upper sequence of hard grey volcanolithic sandstone and dark grey mudstone with minor interbedded volcanics and volcanic conglomerate. The proportions of the rock types vary widely from place to place: conglomerate, in particular, is a minor constituent in the south and southeast, and in places acid volcanics are dominant near the top of the formation.

South of the Saint Lawrence/Croydon homestead road, the Carmila Beds consist of thick-bedded to massive acid to intermediate volcanics interbedded with equal quantities of well bedded cross-bedded volcanolithic sediments and minor conglomerate, overlain by well bedded volcanolithic sandstone, granule conglomerate, and mudstone with minor interbeds of volcanics. Plants are well preserved in some ashstones(?) within this sequence.

Near Tooloombah homestead and farther south, the unit consists mainly of volcanolithic sediments; primary volcanics constitute only about 20 percent. Volcanolithic sandstone and siltstone directly overlie the Connors Volcanics. Fossiliferous calcareous tuff, limestone, and calcareous volcanic sandstone occur near the top of the formation. West of the Broadsound Range, acid to intermediate volcanics predominate.

North of Marlborough the Carmila Beds appear to consist of three parts. Sheared acid crystal tuffs, cropping out west of Glenprairie homestead, are probably the oldest Carmila Beds in the area. These are overlain by volcanolithic sediments, overlain in turn by primary volcanics with calcareous tuff and limestone beds containing abundant marine fossils. This subdivision is easily recognized north of Glenprairie homestead, where the sequence dips to the southwest and is not complicated by tight folding. Southwest of Glenprairie homestead the Carmila Beds are tightly folded and sheared, and probably overturned in places. The basal part near Glenprairie homestead consists mainly of acid crystal tuffs, containing quartz and feldspar phenocrysts and lithic fragments, interbedded with agglomerate, volcanic conglomerate, fine-grained sandstone, and siltstone. These are extremely sheared; the sediments are phyllitic and the crystal tuffs resemble knotted schist. The shear planes dip steeply to the southeast, towards an area of low relief which is probably underlain by intrusives. The middle and upper parts are best exposed 10 miles northwest of Glenprairie homestead. The middle part consists of cream siliceous rhyolitic tuff and ashstone interbedded with volcanic-pebble conglomerate, sandstone, siltstone, and argillite. The sediments are thinly bedded and show graded bedding in places, and include repetitions of coarse-grained grey-white tuff grading to grey ashstone, and thick beds of dark blue argillite and mudstone. The upper part consists of interbedded cobble to granule agglomerate and volcanic conglomerate, flows and tuffs, and richly fossiliferous calcareous tuff and limestone beds, overlying thick sequences of flow-banded trachyte, agglomerate, and autobreccia. These rock types also occur in the folded area, west and southwest of Glenprairie homestead, together with thick sequences of thinly colour-banded to massive siltstone and coarse-grained reworked tuffs, consisting of clasts of quartz, feldspar, and lithic fragments in a dark argillaceous matrix. At the western edge of the folded area southwest of Glenprairie homestead the rocks are similar to those in the upper part of the sequence in the north and contain a similar fauna. They are regarded as the upper part of the Carmila Beds, despite their easterly dip apparently beneath the bulk of the Carmila Beds.

Four miles northwest of Marlborough, dark blue to grey chert and dark green spilitic(?) volcanics are associated with acid crystal tuffs and plant-bearing lithic sandstone and conglomerate. The latter rocks are typical of the Carmila Beds and the chert and basic volcanics are tentatively included in the unit.

The Carmila Beds are preserved in shallow synclines in the Connors Volcanics and elsewhere dip off structurally high blocks of Connors Volcanics. The complex structural relationship of the Carmila Beds to the block of Connors Volcanics south of Tooloombah homestead is discussed on page 76.

The Back Creek Group is structurally conformable on the Carmila Beds in most places, but south of Tooloombah homestead the Group lies directly on the Connors Volcanics, disconformably overlapping the Carmila Beds.

The Carmila Beds dip to the east-northeast in the north of the Saint Lawrence Sheet area. They are tightly folded in the limb of a syncline 4 miles northwest of Saint Lawrence. Farther south, the unit dips east into the trough of the Strathmuir Synclinorium. Northwest of Glenprairie homestead, the Carmila Beds crop out along the eastern limb of the synclinorium; 2 miles northwest of Glenprairie homestead, the eastern limb is cut by a vague northeast-trending lineament which is probably a zone of faulting. East and south of this lineament, the Carmila Beds are sheared and more tightly folded into asymmetrical folds whose axial planes dip east.

The contact between the Carmila Beds and the serpentinite bodies near Marlborough appears to be a high-angle reverse fault dipping southeast at about $65^{o}$. Farther west, a fault zone separates the Carmila Beds from the Back Creek Group.

The good bedding of the Carmila Beds and the abundance of primary volcanics and of reworked volcanic detritus indicate aqueous deposition close to active volcanic centres. Marine fossils in the top part of the unit south of Saint Lawrence mark a local marine transgression: only plant remains have been found lower. Deposition probably commenced with vulcanism and contemporaneous lacustrine(?) sedimentation; as vulcanism waned, mainly reworked volcanics interbedded with some widespread tuffs were deposited; finally the sea invaded most of the area, accompanied by renewed vulcanism in some places.

The thickness of the Carmila Beds is unknown. Northwest of Glenprairie homestead and north of Tooloombah homestead the dips suggest a thickness of about 10,000 feet.

Marine fossils collected from five localities near the top of the Carmila Beds have been identified as Lower Permian (possibly basal Artinskian) and belong to Faunas I or II (App. 1); the whole unit is probably Lower Permian.

Rookwood Volcanics

The Rookwood Volcanics are a newly recognized unit defined here. The name is derived from Rookwood homestead in the Duaringa Sheet area. The type area of the unit is along Melaleuca Creek. The formation consists dominantly of spilitic lavas and crops out in the east of the Duaringa Sheet area, extending east and southeast into the Rockhampton and Monto Sheet areas.

In the Duaringa/Saint Lawrence area, the Rookwood Volcanics crop out in four areas : a 20-mile belt extending north and south from Rookwood homestead; along the eastern edge of the Boomer Range, north of Tynan homestead; in a narrow strip near the Fitzroy River, west of Hillview, Craigilee, and Armagh homesteads and extending southeastwards to the eastern boundary of the Duaringa Sheet area; and in the northeast of the Duaringa Sheet area 6 miles west of Redbank homestead. The volcanics are resistant to erosion and are well exposed. They support open woodland which produces a light-toned pattern on air-photographs.

The Rookwood Volcanics consist mainly of spilitic pillow lavas, with minor agglomerate, volcanic breccia, and chert; tuffaceous sandstone and siltstone are also present. The spilitic volcanics make up 95 percent of the unit. They are hard fine-grained greenish grey rocks; intersertal textures prevail, with albite and oligoclase phenocrysts in a groundmass of chlorite, calcite, epidote, and glass. Vesicles and amygdales of calcite and chlorite are abundant in some rocks. Pillow structures are characteristic: very good examples were seen 1/4 mile south, 1 mile northwest, and 1 mile southwest of Ohio homestead, and in two exposures in the Fitzroy River 4 miles northeast of Tynan homestead (1 mile north of the road crossing), and 1 mile southwest of Hillview homestead. The pillows range from 6 inches to about 3 feet in diameter; the smaller pillows are round and the larger ones are ovoid (Pl. 2, fig. 1). They have a thin fine-grained skin and radial cracks; some have a thin vesicular layer beneath the skin. Small segregations of green fine-grained partly silicified limestone or marl occupy some spaces between pillows.

The agglomerate consists of large fragments of spilite and tuff in a tuffaceous matrix; it is best exposed in the Fitzroy River southwest of Hillview homestead, where pillow lavas grade into agglomerate. Chert is common near the Fitzroy River southwest and south of Armagh homestead; it is mainly thin-bedded and blue-green, but in places is massive.

The Rookwood Volcanics are essentially massive; bedding trends cannot be discerned on the air-photographs and no reliable dips were seen. The relationships with overlying and underlying formations were difficult to establish in the field because exposed contacts are very rare. However, field observations and regional distribution indicate that they unconformably overlie the Rannes Beds, Silurian-Devonian rocks, the Devonian-Carboniferous Yarrol Basin sequence, and the Lower Permian Youlambie Conglomerate, and that they are overlain by the Boomer Formation.

Unconformity between the Rookwood Volcanics and the Rannes Beds was inferred from field evidence 2 miles northwest of Rookwood homestead, where both units dip to the east. Here, a ferruginous bed containing a few angular blocks of sedimentary rock and some quartz pebbles was interpreted as a basal bed of the volcanics marking the unconformity. This bed is best exposed just east of the small intrusion in the Rannes Beds, 3 miles northwest of Rookwood homestead.

North of Tynan homestead, the Rookwood Volcanics overlie Silurian-Devonian volcanics and have been thrust-faulted against the Boomer Formation.

West of Hillview and Craigilee homesteads, on the west limb of the Craigilee Anticline, the Rookwood Volcanics unconformably overlie Silurian-Devonian volcanics, Lower Carboniferous sediments and the Neerkol Formation.

South of Armagh homestead, where the west limb of the anticline swings eastward, the volcanics overlie the Youlambie Conglomerate. Part of the contact here is faulted. In the Fitzroy River area, 3 miles southwest of Armagh homestead, the Conglomerate is overlapped by the Rookwood Volcanics, which overlie the Upper Carboniferous Neerkol Formation.

West of Redbank homestead, the volcanics are unconformable on the undifferentiated Devonian-Carboniferous sediments and the Youlambie Conglomerate.

The Rookwood Volcanics are overlain by, overlapped by, and locally interfinger with the Boomer Formation. Contacts are well exposed both in the Fitzroy River 5 miles southwest of Armagh homestead (just north of the road crossing), and in the Boomer Range 8 miles north of Rookwood homestead.

At the Fitzroy River locality, massive pillow lavas appear to be conformably overlain by thinly bedded tuffaceous sediments, a ferruginous bed* and fine-grained well sorted lithic sandstone. The contact between the units in this area is overturned in places. In the Boomer Range, north of Rookwood homestead, the Rookwood Volcanics overlie Silurian-Devonian volcanics. Only the uppermost two flows of pillow lava, separated by about 10 feet of interbedded thin-bedded lithic sandstone and siltstone typical of the Boomer Formation, are represented. The lower part of the Rookwood Volcanics is not exposed because of overlap. The top flow is apparently conformably overlain by the Boomer Formation. Farther north, the Boomer Formation has apparently overlapped the Rookwood Volcanics.

At Rookwood homestead, the volcanics are intruded by a granodiorite stock. The intrusive relationship is well exposed in the side of a hill, 1.5 miles southwest of the

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* A sample of the ferruginous bed was semiquantitatively analysed by Australian Mineral Development Laboratories, Adelaide, using emission spectroscopy, with the following results: Copper, 50 ppm; Lead, 10 ppm; Zinc, 400 ppm; Cobalt, 200 ppm; Nickel, 200 ppm; Manganese, 10,000 ppm.

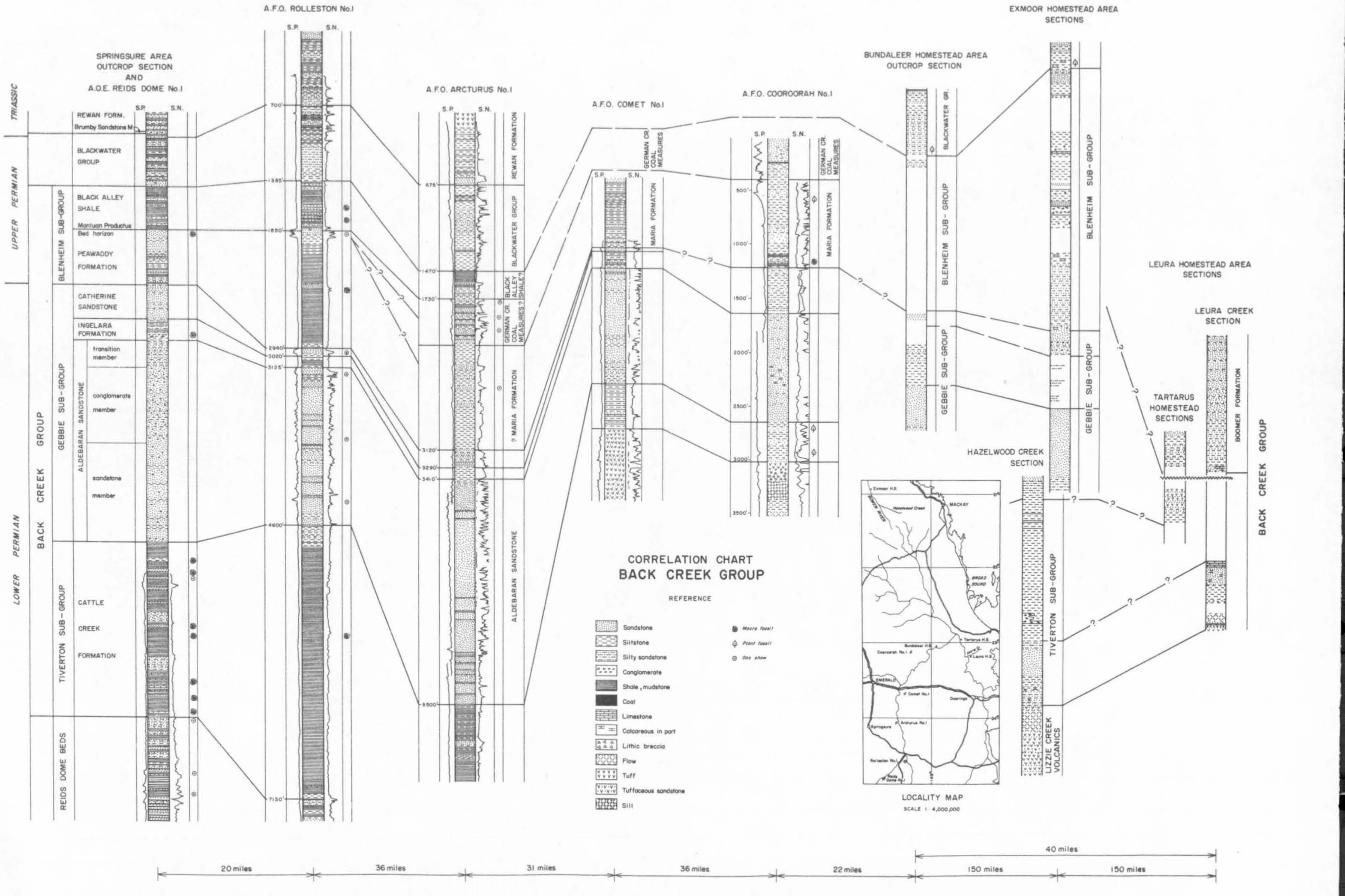


Figure 4 Correlation chart, Back Creek Group.

homestead. The granodiorite has been dated at 240 million years (A.W. Webb, pers. comm.). A small gabbroic stock intrudes the pillow lavas 8 miles south-southeast of Rookwood homestead. A similar stock intrudes the Rannes Beds 3 miles northwest of the homestead and about 200 yards west of the present westerly limit of the Rookwood Volcanics. Both gabbros are mineralogically similar to the spilites and could be late-stage intrusions or perhaps represent the vents through which the spilites were extruded.

The Rookwood Volcanics were laid down in a long narrow marine basin bordered to the west by the sheared and tightly folded Rannes Beds and to the east by competent Silurian-Devonian and Carboniferous volcanics and sediments. The basin extended for about 100 miles from near the northern boundary of the Duaringa Sheet southwards into the Monto Sheet area. The western margin was probably faulted along most of its length.

The extrusion of the spilites was possibly contemporaneous with the emplacement of the ultramafic rocks at Marlborough, just north of the most northerly exposures of the Rookwood Volcanics.

BACK CREEK GROUP (= Middle Bowen Beds)

The Back Creek Group consists of sandstone, siltstone, mudstone, conglomerate, and minor limestone, deposited in a marine or paralic environment throughout the Bowen Basin during the Lower and Upper Permian. Local uplift and periodic regression of the sea resulted in non-deposition in some areas and in changes in the depositional environment from marine to deltaic or fluvial. The fluvio-littoral sediments interfinger with fossiliferous marine sediments and some widespread fossiliferous horizons indicate marine transgressions at times over the entire basin area. The base of the group marks the change from mainly volcanic deposition in the east and freshwater sedimentation in the west to marine sedimentation. The top is a transition to non-marine (coal measure) sedimentation over much of the basin. Both the top and bottom of the group are marked by changes in gross lithology. The Back Creek Group is a lithogenetic sequence of sediments deposited in various depositional environments of the one basin.

The name Back Creek Group was first published by Derrington, Glover, & Morgan (1959) in the Theodore-Cracow area of the Mundubbera Sheet for beds previously mapped as 'Middle Bowen Group' (Hill, 1953). The Theodore-Cracow sequence is now known to be coeval with the 'Middle Bowen' sequence elsewhere in the Bowen Basin, and the name Back Creek Group is adopted for the sequence throughout the Basin.

The type area of the Back Creek Group is in Back Creek in the Mundubbera 1:250,000 Sheet area, where the component formations are the Buffel Formation at the base, and disconformably on it the conformable sequence of the Oxtrack, Barfield, and Flat Top Formations. The disconformity represents a hiatus during most of the upper Lower Permian.

In the northern Bowen Basin, the Back Creek Group consists of a conformable sequence of three subgroups corresponding to Units A, B, and C of earlier reports (Dickins et al., 1964; Malone, 1964). The boundaries between Units A, B, and C mark important changes in depositional environment which can be recognized throughout the Bowen Basin and coincide with formation boundaries in every area; in the Springsure area, these units each consist of 2 or more named formations. Units A, B, and C were named the Tiverton, Gebbie, and Blenheim Formations in the northern Bowen Basin (Malone et al., 1966), but further mapping in the type areas of these 'formations' revealed that each consists of 2 or more distinct formations. Accordingly, they are raised to subgroup rank and the formal names Tiverton, Gebbie and Blenheim Subgroups are applied throughout the Bowen Basin, in place of the informal Units A, B, and C.

The three subgroups can be recognized in most areas throughout the Bowen Basin. A distinct marine macrofauna is associated with each (Dickins et al., 1964): Fauna II with the Tiverton Subgroup; Fauna III with the Gebbie Subgroup; Fauna IV with the Blenheim

Table 1 : Distribution and subdivision of the Back Creek Group in various parts of the Duaringa and Saint Lawrence Sheet areas

| | | Western Duaringa Sheet | South-western Saint Lawrence Sheet | North-western Saint Lawrence Sheet | Bundaleer homestead Area | Connors River Area | Tartarus homestead Area | Strathmuir homestead Area | Boomer and Gogango Ranges | Thuriba homestead Area |
|---|---|---|---|---|---|---|---|---|---|---|
| Back Creek Group | Blenheim Subgroup | German Creek Coal Measures | German Creek Coal Measures | (Undiff.) Blenheim Subgroup | (Undiff.) Blenheim Subgroup | | Boomer Formation | Boomer Formation | Boomer Formation | Boomer Formation |
| | | Maria Formation | (Undiff.) Blenheim Subgroup | | | | | | | |
| | | Thin equivalents present in subsurface | Not exposed | | | | Possibly not deposited | Back Creek Group (Undiff.) | Probably not deposited | Oxtrack Formation |
| | Gebbie Subgroup | | | Not exposed | Gebbie Subgroup | | | | | |
| | Tiverton Subgroup | | | | Not exposed | Back Creek Group (Undiff.) | Back Creek Group (Undiff.) | | Back Creek Group (Undiff.) | Not deposited |

Subgroup. The Tiverton is essentially argillaceous with a coquinitic or calcareous sandy or volcanic formation at the base in the east and north. It crops out discontinuously from the northern Bowen Basin to the Leura homestead area; it is a biostratigraphical and lithological correlate of the Buffel Formation of the Cracow area, but was possibly not continuous with the Buffel Formation. The Gebbie Subgroup consists of quartzose to sublabile sandstone with an argillaceous middle part. The Blenheim Subgroup is essentially silty and includes sublabile to labile sandstone, but on the margin of the basin of deposition includes local coal measures containing more quartzose sandstone. The differences between the three subgroups are probably the result of changes in the areas and environments of deposition; disconformities are suggested by the three different faunas.

The Back Creek Group is widespread in the Duaringa and Saint Lawrence Sheet areas; the units present in various areas are shown in Table 1. Only the Blenheim Subgroup is present in the west, where it consists of the Maria Formation and the German Creek Coal Measures. In the northwestern part of the Saint Lawrence Sheet area the Blenheim Subgroup crops out around the Bundarra Granodiorite; the other subgroups have not been recognized. The Blenheim and Gebbie Subgroups are both exposed in the Folded Zone in the cores of anticlines. Most outcrops of the Back Creek Group cannot be identified with particular formations in the east of the area, where only the Boomer Formation and the Oxtrack Formation could be recognized. The fossil collections in the Saint Lawrence/Leura homestead area indicate the presence of equivalents of the subgroups, but they could not be mapped because the diagnostic lithological changes are masked by an abundance of volcanic detritus. The exposed part of the Boomer Formation is the upper part of the Blenheim Subgroup above the Oxtrack Formation, but its upper limit is nowhere exposed.

In general, the individual formations cropping out in the Duaringa and Saint Lawrence Sheet areas cannot be traced throughout the basin. The German Creek Coal Measures have been tentatively recognized in AFO Arcturus No. 1 Well, where they are equated with the upper part of the Peawaddy Formation, including the Mantuan Productus Bed, and the lower part of the Black Alley Shale. The Maria Formation also has been tentatively recognized in Arcturus No. 1, where it is equated with the lower part of the Peawaddy Formation (Fig. 4). The German Creek Coal Measures can be traced to the north in the Clermont Sheet area along the western flank of the Bowen Basin. They were not recognized in the Bundaleer homestead area and possibly were only laid down on the margin of the basin. The base of the German Creek Coal Measures was placed at 4000 feet in AFO Cooroorah No. 1 (Fig. 4). Above that depth, the arenites are mainly quartzose or sublabile sandstone; below, they are mainly quartz-poor calcareous labile sandstones. A similar change in the arenites occurs at the boundary of the German Creek Coal Measures and the Maria Formation in outcrop.

## Undifferentiated Back Creek Group

The undifferentiated Back Creek Group crops out in 2 areas: in a discontinuous belt from Leura homestead in the south to Saint Lawrence in the north, and in a narrow belt along the Bruce Highway from Clarke Creek in the south to the northern boundary of the Saint Lawrence Sheet area. Fossils belonging to Faunas I, II, & III have been found in the Back Creek Group in these areas, but subdivision in the subgroup was not possible because the diagnostic lithological changes associated with them are masked by an abundance of volcanic detritus.

### Leura homestead - Saint Lawrence belt

The Back Creek Group in the east lies above the Carmila Beds and below the Boomer Formation. In a few places it has overlapped the Carmila Beds and directly overlies the Connors Volcanics. It crops out around the flanks of the Broadsound Range, around the dome of Connors Volcanics east of Leura homestead, in a broad area extending north from Apis Creek homestead to the Styx River, and in areas northwest of Marlborough and west

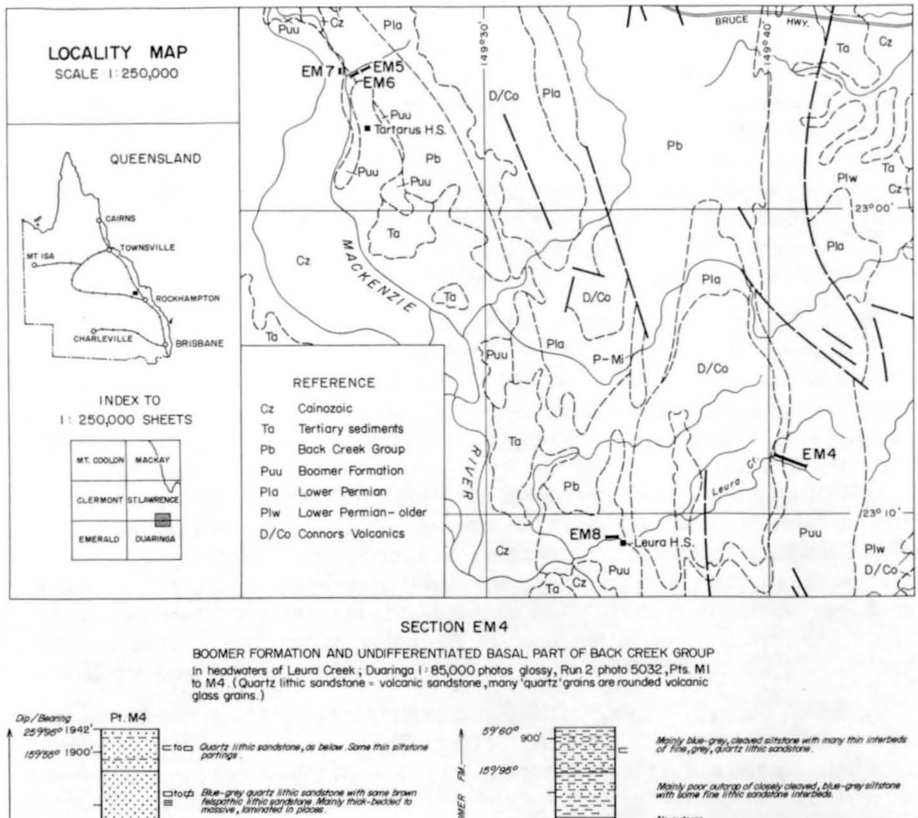


**Figure 5 Measured section EM4, Boomer Formation, Leura homestead area.**

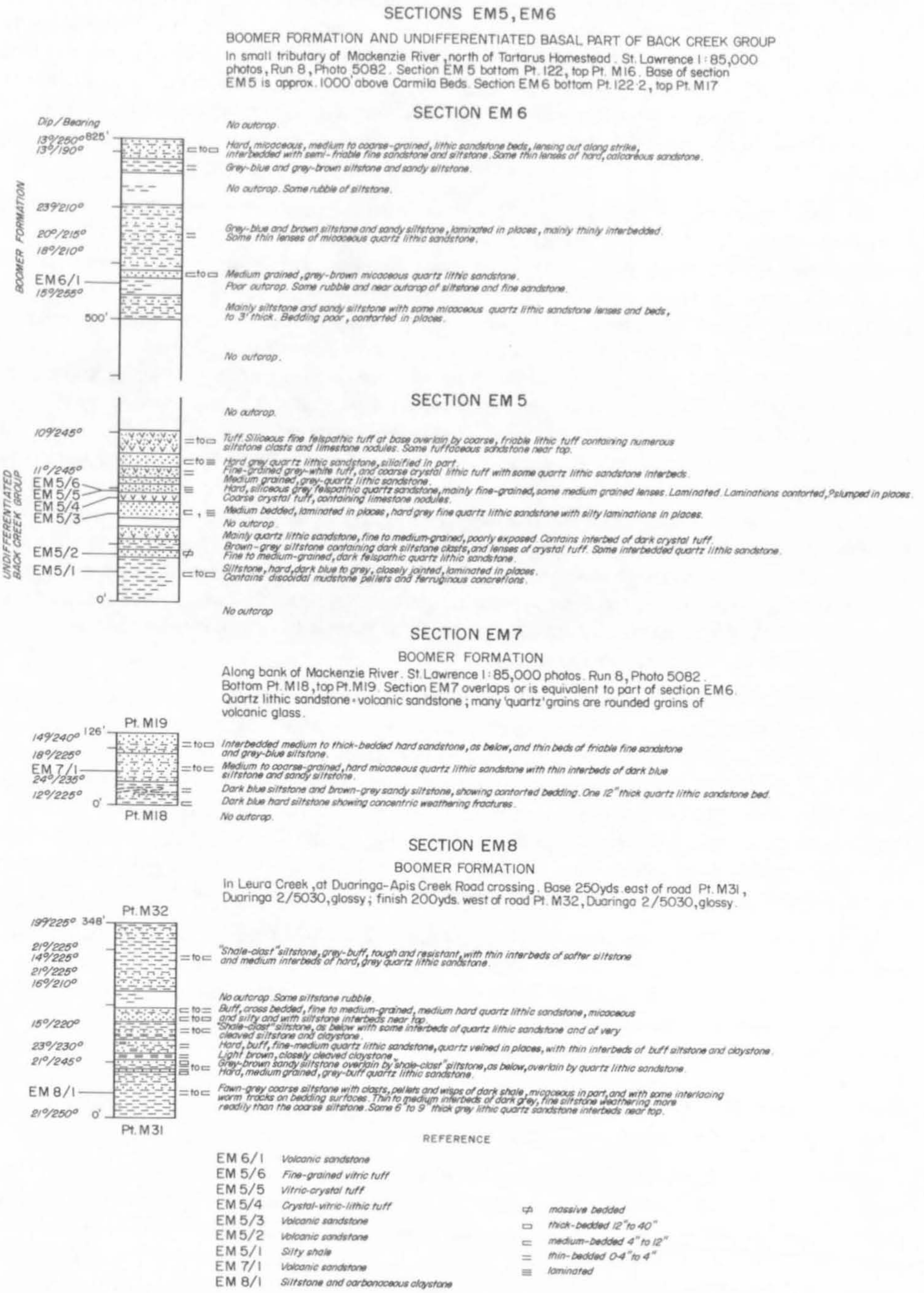


Figure 6 Measured sections EM5, 6, 7, & 8, Boomer Formation, Leura homestead area.

of Saint Lawrence. A rugged landscape, with deeply incised dendritic drainage, has developed on the unit in the foothills of the ranges, which are mainly composed of volcanics; away from the ranges the group is eroded to low rounded hills and strike ridges. In the ranges, the Back Creek Group has a thin rubbly soil cover supporting dense scrub growth. In the lower country it has a deep soil cover and is commonly cleared for pasture improvement or cultivation; here, the best and in some places the only exposures are found in creek sections.

The rock types cropping out west of the Broadsound Range are partly displayed in the measured section EM5 (Fig. 6), which covers that part of the Back Creek Group from about 1000 to 1300 feet above the base. It contains much primary volcanic material, both as tuff and in tuffaceous sandstone, interbedded with volcanolithic sandstone and siltstone. The poorly exposed basal 1000 feet of the Back Creek Group in this area contains rock types similar to those in section EM5, as well as coarse to fine-grained calcareous volcanic sandstone interbedded with vitric tuff, and fossiliferous calcareous sandstone and sandy limestone containing abundant volcanic detritus. This part of the group is very similar to the basal 650 feet of section EM4 (Fig. 5), in the headwaters of Leura Creek. The top of the undifferentiated Back Creek Group and the base of the overlying Boomer Formation is stratigraphically between sections EM5 and EM6 (Fig. 6). These sections are separated by about 200 feet of concealed section. The Boomer Formation is possibly disconformable on the undifferentiated Back Creek Group. Lithologically, the change is marked by the disappearance of primary volcanic material; sediments of the Boomer Formation were derived from a volcanic terrain but do not appear to contain primary volcanics. The base of the Back Creek Group was not observed west of the Broadsound Range, but the unit appears to be structurally conformable on the Carmila Beds.

Two fossil collections were made west of the Broadsound Range. Collection Du686 comes from a horizon equivalent to about the middle of section EM5, though the locality is about 2 1/2 miles north of the section line. This collection belongs either to Fauna III or Fauna IV (App. 1) of Lower to Upper Permian age. Collection Du2158 comes from the base of the Back Creek Group about 5 miles north of section line EM5. This collection is Lower Permian and belongs to Fauna II (App. 1); both lithology and fauna suggest correlation with sequences at the base of the Back Creek Group, 7 miles southeast of Croydon homestead (Yatton Limestone, Laing, in Hill & Denmead, 1960) and at the base of section EM4 (Fig. 5).

The Back Creek Group sediments cropping out south of the Broadsound Range and around the dome of Connors Volcanics east of Leura homestead are similar to the sequence west of the Broadsound Range. The whole sequence exposed east of the Connors Volcanics dome is illustrated in the basal 650 feet of section EM4. The lithology and faunas indicate that this sequence represents only the basal part of the Back Creek Group. It unconformably overlies the Connors Volcanics and is unconformably overlain by the Boomer Formation. At the northern end of the Connors Volcanics dome, the Back Creek Group unconformably overlaps the Carmila Beds.

Similar unconformable overlaps were mapped west of Apis Creek. In this area, the basal bed of the Back Creek Group is a tuff or tuffaceous sandstone which contains fossils (Du745, App. 1) belonging to Fauna II. Farther north, this bed has overlapped the Carmila Beds and unconformably overlies the block of Connors Volcanics south to Tooloombah homestead. These depositional overlaps are possibly the result of movement of blocks of Connors Volcanics during deposition of the Back Creek Group. The Back Creek Group in the Apis Creek area appears to include more, presumably younger, section than is present west of the Broadsound Range. Rock types are generally similar in the two areas, but siltstone and volcanic sandstone are dominant in the upper part of the section in the Apis Creek area, primary volcanics are relatively minor, and blue nodular siltstone is present near the top; some of the nodules contain fossils and the rock is similar to nodular siltstone in the Gebbie Subgroup near Bundaleer homestead. The youngest beds crop out in the trough of the Apis Creek Syncline. East and north of the syncline, older beds of the group crop out on a structurally complex faulted anticline. The rock types exposed include tuff and tuffaceous sandstone as well as interbedded volcanolithic sandstone and siltstone. East of the ridge, the unit dips regionally east and is overlain, possibly conformably, by the Boomer Formation.

North of Tooloombah homestead, the Back Creek Group sediments are poorly exposed. They dip to the east, appear to be conformable on the Carmila Beds to the west, and are unconformably overlain by the Styx Coal Measures to the east. Volcanic sandstone and siltstone are the dominant rock types. Marine fossils collected by Reid (1924) from the youngest exposed beds, immediately below the Styx Coal Measures, are referred to Fauna III.

Near Saint Lawrence, the Back Creek Group is poorly exposed. Rock types present include fossiliferous calcareous tuff and tuffaceous sandstone and grey mudstone containing spherical concretions, some of which contain fossils. Two fossil collections, SL346 from the calcareous tuff and SL370 from the concretionary mudstone, are referred to Faunas I or II. The similarity between these collections and collections from the top of the Carmila Beds indicate that there was little or no break between the two units in this area.

The only other area of undifferentiated Back Creek Group is northwest of Marlborough. This block is unconformably overlain by Tertiary sediments to the south, is possibly conformably overlain by the Boomer Formation in one area, and is faulted against the Boomer Formation to the west, and the Carmila Beds and serpentinite to the east. The unit includes the following rock types: grey-buff siltstone interbedded with grey or brown lithic or quartz lithic sandstone; blue-grey siltstone containing ferruginous nodules, lenses, and laminae, as well as lenses of quartz-pebble conglomerate and pebbly sandstone; interbedded blue-grey and purple nodular siltstone, calcareous in part and containing some crinoids and other fossils; tuffaceous sandstone, grading from granule conglomerate to medium-grained sandstone, with siltstone interbeds; and rare hard green volcanic conglomerate. The sequence is jointed and quartz veined; the siltstone is commonly sheared and in places has slaty cleavage. Marine fossils were observed at a number of localities, but rarely included diagnostic species. A collection at the Geological Survey of Queensland from a locality near the railway line, 9 miles northwest of Marlborough, was determined as Fauna III, of Lower Permian age. Equivalents of the oldest rocks in the Back Creek Group do not appear to be exposed in this area. Apart from the absence of Fauna II fossils, rock types similar to those in the basal part of section EM4 were not observed in this area. These rocks are separated by Tertiary sediments and Cainozoic cover from outcrops of Rannes Beds. It is possible that the Rannes Beds include equivalents of the basal part of the Back Creek Group.

West of the Broadsound Range, the Back Creek Group dips southwest at $10^{\circ}$ to $30^{\circ}$; the sediments are jointed but not cleaved. South of the Broadsound Range, the group is folded into anticlines and synclines, which plunge south at about $15^{\circ}$ and have flank dips of about $20^{\circ}$ to $40^{\circ}$; the easterly dips are generally steeper. The lutites display steeply east-dipping cleavage, which is common in the Back Creek Group east of the Broadsound Range. The group dips off the Connors Volcanics exposed in the core of the complex dome east of Leura homestead. The sediments are intensely sheared and tightly folded in the elongate embayment into the dome from its southern margin; this embayment may be the result of faulting of the Connors Volcanics block. The Back Creek Group is broadly and asymmetrically folded in the Apis Creek Syncline, the eastern limb being steeply dipping. East and northeast of the Apis Creek Syncline, the group is tightly and complexly folded, faulted, and sheared; some of the fold axes are overturned and dip steeply east. Farther north, the tight folding dies out and the unit dips regionally to the east at $20^{\circ}$ to $40^{\circ}$. The group is poorly exposed west of Saint Lawrence and the structure is unknown; it is probably conformable on the Carmila Beds, which are moderately to tightly folded. The Back Creek Group is tightly folded and faulted in the areas west and northwest of Marlborough. Graded bedding indicates that some steeply east-dipping beds are overturned. East-dipping cleavage is common in the lutites.

Marine fossils are widespread; the basal part of the group includes richly fossiliferous limestone and calcareous tuffaceous sandstone containing an abundant neritic fauna which, together with the coarseness of the tuffaceous clasts, suggests nearshore deposition. The distribution of the calcareous sediments relative to the Connors Volcanics and the complex overlapping relationships of the various units suggest that the blocks of Connors Volcanics were probably land at times during Lower Permian deposition. The presence of primary volcanics in the unit indicates contemporary vulcanism. The volcanics are dominantly tuffs; flows are rare or absent. This suggests that the volcanic centres were terrestrial and that the terrestrial volcanics were reworked to supply the sediments which dominate the unit as a whole. Primary volcanics are rare in the upper parts of the Back Creek Group in the Apis Creek area, suggesting that vulcanism had ceased before the last beds were deposited.

Fossils belonging to Faunas II and III are present in the Apis Creek and Marlborough areas, where the contact with the overlying Boomer Formation may be conformable. Progressively older rocks to the south beneath the Boomer Formation suggest that the sea was regressing northwards while rocks containing Faunas II and III were being deposited. During most of this time, the eastern part of the Duaringa Sheet area was probably being eroded. Farther south, in the Monto Sheet area, the Buffel Formation, containing a fauna found low in the Tiverton Subgroup, is similarly unconformably overlain by the Oxtrack Formation containing Fauna IV.

The palaeogeography in the east of the Duaringa and Saint Lawrence Sheet areas during the deposition of the Back Creek Group was complex. A shallow sea surrounded islands of Connors Volcanics in at least the northeastern part of the Duaringa Sheet area and may have extended south into the Monto Sheet area during deposition of equivalents of the Yatton Limestone and the Buffel Formation. Subsequently, the sea regressed to the north and west, where the Gebbie Subgroup and its equivalents were deposited, while the eastern part of the Duaringa Sheet area emerged. At this time, the sea probably extended across the present position of the Connors and Broadsound Ranges from the Apis Creek/Saint Lawrence area to the Bowen Syncline area.

The Back Creek Group is about 1300 feet thick west of the Broadsound Range and about 650 feet thick in section EM4 east of Leura homestead. It is probably more than 2000 feet thick in the Apis Creek Syncline and farther north. The fossils are discussed in Appendix 1. They are all Lower Permian.

### Bruce Highway belt

The Back Creek Group forms a discontinuous belt of outcrop west of the Connors Range along the Bruce Highway, striking north-northwest and dipping gently to the west. It has been eroded to form flat country with some rounded hills and long gentle slopes. In a few places, such as near Yatton Creek, calcareous tuffaceous sediments form small strike ridges. Outcrop is generally poor and most of the area is covered by brigalow scrub.

The group conformably overlies the Lizzie Creek Volcanics in the north; farther south, it overlaps the Lizzie Creek Volcanics and unconformably overlies the Connors Volcanics. Only the basal 1500 feet or so is exposed, and this probably belongs to the Tiverton Subgroup. Overlying units are obscured by Cainozoic cover.

The base is well exposed 10 miles north-northeast of Yatton homestead, near the Bruce Highway, where a brown fossiliferous limestone, the Yatton Limestone (Laing, in Hill & Denmead, 1960, pp. 202-204, 208), overlies massive andesitic volcanics of the Connors Volcanics. Farther north, in Sheepskin Creek, at least 400 feet of blue micaceous siltstone, containing abundant small rounded pebbles, crops out at the base of the Back Creek Group, overlying interbedded black tuff and andesite of the Lizzie Creek Volcanics. Farther north still, near Main Range Creek, the base is a blue calcarenite containing well preserved marine fossils. Above the calcarenite is 1400 feet of dark blue thin to medium-bedded micaceous siltstone, closely jointed in places. The siltstone contains 10 percent of rounded pebbles of quartz, volcanic rocks, and coarse siltstone; the maximum diameter of the pebbles is 3 inches and the average is 1/2 inch. The siltstone also contains calcareous concretions up to 6 inches in diameter.

The regional dip is about $15^{o}$ to the west, but locally the dip may increase and small folds and faults interrupt the regional pattern. A small anticline near Cardowan homestead plunges to the southwest; the eastern limb of this structure has been faulted. The Yatton Limestone is folded into a south-plunging syncline, the eastern limb of which is displaced half a mile by a fault.

Fossils were collected from four localities in this area. They belong to the Lower Permian Fauna II and are discussed in Appendix I. The rock types observed in the Connors River area are lithologically similar to those in the type Tiverton Subgroup. The fossils in the unit confirm this correlation.

## GEBBIE SUBGROUP

The name Gebbie Formation was introduced by Malone et al. (1966). Later mapping revealed three component formations, a basal sandstone, a vertically intergrading siltstone-sandstone in the middle, and a sandstone at the top. The type section is in Gebbie Creek in the Bowen Sheet area.

The Gebbie Subgroup crops out in north-northwesterly structures near Bundaleer homestead, extending across the boundary between the Duaringa and Saint Lawrence Sheet areas. It is well exposed along and near the northern bank of the Mackenzie River and in small creeks farther north. It is overlain in places by residuals of Tertiary sediments and crops out on the flanks of some mesas capped by lateritized Tertiary sediments. Apparently the Gebbie Subgroup was eroded to a mature topography on which the Tertiary sediments accumulated. Subsequent erosion stripped off most of the Tertiary sediments and dissected the Gebbie Subgroup in places to a depth of about 50 feet below the base of the Tertiary sediments.

The lithology of part of the subgroup in the Bundaleer area is illustrated in measured section EM11 (Fig. 11). This 800-foot section includes the oldest rocks exposed in this area, including part of the basal sandstone and part of the middle siltstone-sandstone. The remainder of the Gebbie Subgroup present in the area could not be measured because of poor exposure and complicated folding. The top part of the unit includes several thick sandstone beds whose lithology is very similar to that of beds in the lower part of section EM11; they probably represent the upper sandstone.

The sandstone is mainly sublabile; of the grains quartz makes up about 75 percent, and lithic grains (mainly vitric tuff) are more abundant than plagioclase. This rock is a more mature equivalent of the volcanolithic sandstone which dominates the Back Creek Group farther east. Quartz is more abundant because it is farther from the eastern source and because quartz-rich detritus is supplied from the west. The matrix is generally argillaceous and micaceous; calcite and siderite aggregates are common. A distinctive rock in the unit is a grey-blue nodular siltstone, weathering brown, which contains hard well rounded dark blue nodules, spherical or ovoid and commonly formed about a fossil or fragment of calcareous material. Pinkish brown limestone, unfossiliferous and probably of inorganic origin, crops out in the sequence in a few places as thick blunt-ended lenses, up to 6 feet thick and 50 feet long. The bedding of the underlying, and to a lesser extent of the overlying, sediments is deformed, but usually not disrupted, around the limestone. These may be slump masses or post-depositional concretions which have differentially compacted the underlying sediments.

The Gebbie Subgroup crops out west of Bundaleer homestead in anticlines and synclines in the core of an anticlinorium with a total amplitude probably greater than 3000 feet. The eastern flank of the anticlinorium is covered, but on the western flank rocks of the Blenheim Subgroup and Blackwater Group crop out in numerous minor folds. The style of folding is illustrated in Figure 10. The axes of the folds are apparently horizontal near the Mackenzie River, but plunge to the northwest and southeast at opposite ends of the structure.

The Blenheim Subgroup is poorly exposed in the structure near Bundaleer homestead but appears to be conformable on the Gebbie Subgroup, whose base is not exposed.

The Gebbie Subgroup was deposited in a shallow to moderately deep sea. Some of the fossils, particularly those from the siltstone nodules, are the remains of animals which lived in muddy water below the limit of wave action. The abundance of cross-bedding in the sandstone indicates deposition from currents in relatively shallow water.

The 800 feet of section EM11 represents more than half of the subgroup, which is probably about 1200 to 1500 feet thick in this area.

Ten fossil collections were made, six from the siltstone represented by the upper part of section EM11 and four from the underlying sandstone. The six upper collections are all from about the same stratigraphic position as specimens EM11/1 and EM11/2, in measured section EM11, Figure 11. They belong to the Lower Permian Fauna III and are associated with the middle unit of the Gebbie Subgroup in its type area. The fossils and the rock types suggest correlation with the Ingelara Formation, which is the middle unit of the Gebbie Subgroup in the Springsure area (Mollan et al., 1969). The fossils in the lower sandstone are compatible with its being the basal unit of the Gebbie Subgroup: it is probably equivalent to the Aldebaran Sandstone of the Springsure area.

## BLENHEIM SUBGROUP

The Blenheim Subgroup is widespread in both Sheet areas. In the Saint Lawrence Sheet area, the Subgroup has not been subdivided; it crops out in small isolated areas south of the Bundarra Granodiorite, in the cores of anticlines in the Folded Zone, and in the south-west of the Sheet area. In the Duaringa Sheet area the Maria Formation and German Creek Coal Measures crop out in the west, and the Oxtrack Formation in a small area in the south-east at Thuriba homestead. The Boomer Formation, which conformably overlies the Oxtrack Formation, crops out extensively in the Gogango and Boomer Ranges; it is probably equivalent to part of the Blenheim Subgroup.

The Blenheim Subgroup is exposed in a line of high rugged hills adjacent to the Bundarra Granodiorite, but disappears under soil cover a little way to the south. The rock types present include quartz sandstone and lithic quartz sandstone, indurated and foliated in places, and dark purple and white sandy siltstone, micaceous and calcareous in places. Contact-metamorphosed rocks near the intrusive include andalusite hornfels and graphitic schist. No fossils were found in the Saint Lawrence Sheet area, but fossils belonging to Fauna IV (App. 1) were found a few miles to the northwest in the Mount Coolon Sheet area.

In the Folded Zone, the Blenheim Subgroup crops out in the cores of anticlines and domes and is poorly exposed on the west flank of the anticlinorium near Bundaleer homestead. Topography throughout the Folded Zone is extremely subdued and outcrop is confined to creeks and gullies and other areas of recent dissection. Bedding trends are emphasized on the air-photographs by vegetation trends. The Blenheim Subgroup cannot be distinguished from the overlying Blackwater Group on the air-photographs, but once the boundary has been established on the ground it can usually be extended for some miles, using the bedding trends visible on the photos.

The unit consists of an interbedded sequence of sandstone, siltstone, and shale, and contains thin but widespread and distinctive beds of sandy coquinite. Apart from the coquinite, the sediments are not markedly unlike the overlying Blackwater Group. The sandstone is generally sublabile and moderately well sorted, and the vertically intergrading sandstone-siltstone sequences common in the Blackwater Group are generally absent. The sandstone contains worm tracks. Dark blue-grey shale and carbonaceous mudstone are interbedded with the sandstone in places; they commonly contain silty interbeds and much carbonized plant material, including poorly preserved plant fossils. The siltstone is dark grey or blue, very jointed and splintery, and is micaceous in places; a few beds contain carbonaceous pyritic mudballs.

The structures in which the unit is exposed range from tight sharp-crested anticlines to gently folded structures such as that near Barwon Park homestead. The Blenheim Subgroup is conformably and possibly transitionally overlain by the Blackwater Group. The contact with the Gebbie Subgroup is obscured near Bundaleer homestead, the only locality in this area where older rocks are exposed.

Eight fossil collections from the Folded Zone probably belong to Fauna IV of Upper Permian age.

Sediments of the Blenheim Subgroup not assignable to a formation crop out on the western flank of the Bowen Basin in the southwestern corner of the Saint Lawrence Sheet area, where they are overlain by the German Creek Coal Measures. In this area, the subgroup is a gently dipping sequence, on which a very subdued topography has developed; the best exposures are in the headwaters of German Creek. The sequence probably includes less than 100 feet of section consisting dominantly of grey-blue micaceous sandy siltstone and silty sandstone and dark carbonaceous mudstone. The sediments contain abundant worm tracks and tubes and some crinoid ossicles. They are poorly sorted except for some hard beds of moderately well sorted sandstone which are interbedded with the sandy siltstone near the base of the exposed section. Some lenses of hard calcareous sandstone are present; these commonly contain worm tracks and tubes and may be concretionary in origin. The base of the Blenheim Subgroup is not exposed; some miles to the west, in the Clermont Sheet area, it is unconformable on pre-Permian rocks. In AFO Cooroorah No. 1 Well, 15 miles to the southeast, the Blenheim Subgroup is underlain by the Gebbie Subgroup (Fig. 4), and overlaps it northwest of the well.

<u>Maria Formation</u> (Derrington, Glover, & Morgan, 1959)

The Maria Formation crops out south of the Mackenzie River in the crests of small sinuous anticlines. It gives rise to a very subdued topography, and is best exposed on the flanks of mesas and cuestas capped by resistant sandstone of the overlying German Creek Coal Measures. Only the top 200 feet or so is exposed; the top 100 feet is mainly micaceous siltstone (measured section R7, Fig. 7). Elsewhere, thin to medium beds of sandstone are interbedded with the siltstone, but the formation is dominantly argillaceous. The sandstone is generally an argillaceous feldspathic sublabile to labile cross-bedded sandstone containing up to 40 percent calcite or siderite cement. Most of the few lithic grains are dark mudstone clasts. Carbonaceous matter constitutes up to 10 percent of some sandstone beds and is abundant in the siltstone and mudstone also; some beds of mudstone contain poorly to well preserved plant remains. Discoidal and spherical calcareous concretions, some up to 3 feet in diameter, are common in some horizons in the sequence. They are either sandy limestone with incipient cone-in-cone structure or calcareous sandstone or marl lenses.

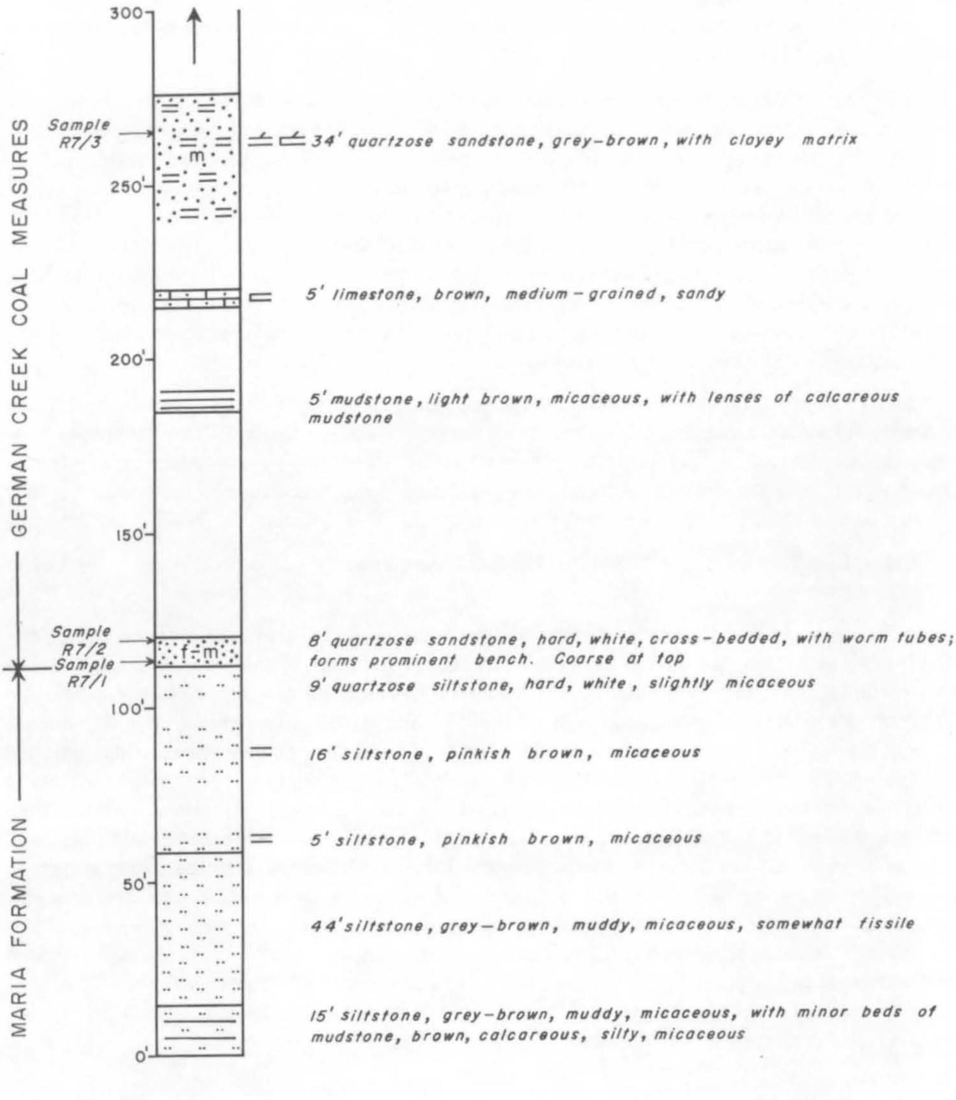


Figure 7 Measured section R7, Maria Formation and German Creek Coal Measures.


Figure 8 Composite lithological column, German Creek Coal Measures.

The Maria Formation is gently dipping to flat-lying and is conformably overlain by the German Creek Coal Measures. The base is not exposed, but in AFO Cooroorah No. 1 and AFO Comet No. 1 Wells (Fig. 4) it is placed above a sandstone unit considered to be equivalent to the Catherine Sandstone (Mollan et al., 1969). Laterally, it is equivalent to part of the Peawaddy Formation to the southwest. No marine fossil localities are known; it is regarded as Upper Permian because of its stratigraphical position.

German Creek Coal Measures

The German Creek Coal Measures are a newly recognized unit defined here: the name is derived from German Creek in the Saint Lawrence Sheet area. The type section is in German Creek (Grid reference: base, 12361363; top, 12611336); the sequence is shown in Figures 7 & 8. The base of the formation is well exposed in a small west-flowing tributary of German Creek, 2 miles north of the base of the type section.

In the northwest of the Duaringa Sheet area, the German Creek Coal Measures are the upper part of the Blenheim Subgroup and are conformable on the undifferentiated Blenheim Subgroup described above. The contact is possibly transitional. In this area, the German Creek Coal Measures have been subdivided into three members : the Crocker Sandstone Member at the base, the Macmillan Member, and the Carnangarra Sandstone Member at the top (Derrington & Morgan, 1959b; Derrington, Glover, & Morgan, 1959). They are not shown on Plate 6. The Carnangarra Sandstone Member lenses out to the north and is not present in the type area of the German Creek Coal Measures, and the Macmillan Member is not recognizable south of the Capricorn Highway. South of the Mackenzie River, the Coal Measures conformably overlie the Maria Formation. The German Creek Coal Measures are overlain, with apparent conformity, by the Fair Hill Formation of the Blackwater Group.

The German Creek Coal Measures crop out in the western part of the Duaringa Sheet area and extend northwest into the Emerald, Clermont, and Saint Lawrence Sheet areas. The unit includes gently dipping sandstone beds which resist erosion to form cuestas and rare mesas up to 200 feet high bounded by steep scarps. The mesas occur where the top sandstone overlies a thick siltstone. The steep reverse slopes of the cuestas are generally benched by sandstone ledges.

The lithology in the type area (Fig. 8) consists of quartzose and sublabile locally argillaceous sandstone, calcareous lithic and feldspathic sandstone, silty sandstone grading to coarse siltstone, mudstone, carbonaceous mudstone, and coal. Most commonly the quartz content of the sandstone constitutes 80 - 95 percent of the framework. Sorting is poor to good; some argillaceous sandstone in the unit contains up to 45 percent of kaolinitic or illitic matrix. Muscovite is a common constituent of both the sandstone and siltstone, and carbonaceous matter is common on bedding plane laminae of the sandstone. Feldspar is consistently present, generally constituting about 5 - 10 percent of the grains but up to 25 percent in some calcareous labile sandstone. Calcite is the most common cement and is very abundant in places; siderite is less common. A few quartz-pebble conglomerate beds and scattered pebble bands are present in the type area. Structures within the sequence include cross-bedding and cross-lamination, abundant worm tubes and trails, and a few ripple-marked surfaces.

The unit thins and changes somewhat in lithology to the south. The basal 300 feet to 400 feet in the type area, an interbedded quartz sandstone/siltstone sequence, apparently either wedges out to the south or becomes predominantly silty, similar to the top part of the Maria Formation. South of the Mackenzie River, the unit consists mainly of quartzose and sublabile sandstone with siltstone interbeds. No dominantly silty unit such as the Macmillan Member can be recognized. Coquinitic calcareous sandstone beds crop out near the base of the unit in many places south of the Mackenzie River and in a few places north of the river.

The German Creek Coal Measures are gently dipping. In the northwest, they dip east on the west flank of the Bowen Basin. Their main area of outcrop is on a broad irregularly folded ridge with many sinuous low-amplitude anticlines and synclines which involve only a small part of the succession. These structures are outlined by bedding trends visible on the air-photographs and by mapped sandstone lenses.

The abundant worm borings, the coquinites near the base, and scattered marine fossils indicate marine deposition for at least part of the time. Results of analysis for trace amounts of boron in the coal seam exposed in German Creek (Pl. 2, fig. 2) suggests deposition in brackish water (D. King, pers. comm.). The small scale of the cross-bedding and cross-lamination and the rare ripple-marked surfaces suggest deposition by gentle currents, probably in fairly shallow water. The environment of deposition was possibly a shallow delta, partly brackish and occasionally inundated by the sea.

The Coal Measures are about 800 feet thick in the type area and thin to about 400 feet south of the Capricorn Highway.

The German Creek Coal Measures south of German Creek contain long-ranging marine fossils belonging to both Faunas III and IV (Dickins et al., 1964); fossils of Fauna IV occur in the Crocker Sandstone Member near Comet. The Coal Measures are Upper Permian (see App. 1).

Oxtrack Formation (Derrington, Glover, & Morgan, 1959)

The Oxtrack Formation crops out in small patches in the southeast of the Duaringa Sheet area on the west limb and north plunge of the Thuriba Anticline. It has not been found on the east limb of the anticline. The formation is widespread in the Monto and Mundubbera Sheet areas to the south (Jensen, Gregory, & Forbes, 1964).

Outcrop is poor in the Thuriba homestead area; the rocks are fossiliferous grey and light brown calcareous siltstone and richly fossiliferous partly recrystallized and silicified calcarenite containing volcanic rock fragments up to 1 inch across. Rich Upper Permian Fauna IV collections, containing brachiopods, pelecypods, corals, crinoids, and bryozoa, were made at several localities (App. 1).

The Oxtrack Formation unconformably overlies the Camboon Andesite, and is overlain by the Boomer Formation; the contacts are obscured. The Oxtrack Formation represents marine neritic sedimentation at the start of a major marine transgression. The thickness of the unit is about 100 feet in this area, but increases to about 500 feet farther south.

Boomer Formation

The Boomer Formation is defined here. The name is derived from the Boomer Range in the Duaringa Sheet area. The type section is in Leura Creek in the Duaringa 1:250,000 Sheet area (Grid references: base, 11662515; top, 11582441); it does not include the top part of the unit. The formation crops out mainly in the Boomer and Gogango Ranges.

The Boomer Formation consists of interbedded very fine to medium-grained sandstone, dark siltstone, and carbonaceous claystone. The sandstone is thick-bedded in a few places where it dominates the section; elsewhere siltstone is dominant. The sandstone is generally volcanolithic or lithic, and poor in quartz. The siltstone commonly contains interworked slumps, mudrolls, and wisps of dark sandy carbonaceous claystone.

The thickness of the formation is unknown, but possibly exceeds 3000 feet; 1250 feet was measured in Leura Creek, but this did not include the whole unit.

The formation crops out mainly in four areas : (1) the Boomer and Gogango Ranges; (2) west of the Broadsound Range at Tartarus homestead; (3) a strip of country east of the

Boomer Range and west of the Old Craigilee homestead and extending southeast into the Rockhampton Sheet area; and (4) a strip extending north from the Boomer Range to the Styx River in the Saint Lawrence Sheet area. The topography is mature near the Mackenzie and Fitzroy Rivers and is moderately rugged in the ranges; it appears to reflect the style of folding of the formation. North of Balcomba homestead, where the formation is gently folded into small domes and basins, the topography includes low strike ridges and cuestas and slightly rounded tabletop hills; farther east, in an area of tight and complex folding, the topography is very broken, though of only moderate relief. Maximum relief is adjacent to blocks of volcanics in the ranges. Strike ridges rising 50 feet to 100 feet above low rolling country are typical of the topography in the Styx River area.

Parts of the formation are shown in measured sections EM4, EM6, EM7, and EM8 (Figs 5 & 6). These measured sections do not cover the whole formation, but do include most of the rock types and illustrate changes in the proportions of arenites and lutites. Conglomerate is present in the upper part of the unit, which is not represented in the measured section; it varies from a polymictic conglomerate with an illite matrix to an argillaceous sandstone containing scattered pebbles. The conglomerate pebbles are mainly sublabile sandstone, in which the quartz grains show strong pressure-solution effects and which contain small amounts of chert, feldspar, and sedimentary rock fragments. Sublabile sandstone is rare in the Duaringa and Saint Lawrence areas, but forms most of the pebbles in conglomerate of the Dinner Creek Beds farther to the east. Other pebbles in conglomerate of the Boomer Formation include volcanolithic and tuffaceous sandstone, vitric-crystal tuff, and tuffaceous claystone. These were possibly derived from the Back Creek Group.

Volcanolithic sandstone is the main arenite. It contains about 15 percent quartz, up to 25 percent albite, 35 percent chert and devitrified glass, and about 15 percent lava, tuff, and sedimentary rock fragments. The matrix is mostly very carbonaceous silty clay; it is rarely cherty. The sandstone is moderately well sorted.

The lutites include argillaceous siltstone and dark carbonaceous silty claystone, which is similar to the matrix of the sandstone. The clasts in the siltstone are similar to those in the sandstone, though the proportion of quartz is a little higher. In the siltstone, quartz, feldspar, and glassy grains are oriented parallel to the bedding, and cleavage of illite flakes is oriented at a steep angle to the bedding. Cleavage is common in the lutites (Pl. 3, fig. 1), except in outcrops west of the Broadsound Range. The claystone consists mainly of well oriented illite flakes and cherty material with abundant thin corrugated shreds of carbonaceous matter. A distinctive rock in the formation is a siltstone containing irregular patches of carbonaceous claystone and brown siltstone. The siltstone is well sorted, average grainsize 0.05 mm, contains angular grains of quartz (30 percent), plagioclase and untwinned feldspar (10 percent), devitrified glass (15 percent), and interstitial greenish grey phyllosilicate (?chlorite) (5 percent). The abundant matrix consists of chert and illite flakes. The other rock types occur in the siltstone as mud rolls and slumps and as completely disrupted slivers and pockets. The brown siltstone contains abundant brown phyllosilicates, possibly devitrified glassy matrix, patches rich in carbonaceous debris, and much hydrated iron oxide. The claystone is silty and contains abundant coaly shreds oriented in the same direction as the illite in the siltstone.

The most characteristic features of the Boomer Formation are the interbedding of rocks differing mainly in grainsize and the lateral persistence of individual beds. The interbedding is best displayed where thin to thick beds of volcanolithic sandstone are interbedded with siltstone, but the same relationship exists between beds of coarse and fine siltstone, and beds of siltstone and claystone. Laterally the beds are remarkably persistent; exposed strike lengths of 100 yards or more showed no changes. The only exception to this was in section EM6 (Fig. 6), which includes lenticular volcanic sandstone beds near the top; but it is near the northwest limit of the formation and is not typical of the unit as a whole.

In gross appearance, the Boomer Formation resembles a flysch facies, but unlike a typical flysch it lacks sole markings and graded bedding.

The intensity of folding of the Boomer Formation varies from place to place. West of the Broadsound Range, it dips southwest at $15^{\circ}$ to $20^{\circ}$ and is uncleaved. Farther south, near Leura homestead, it is folded into broad south-plunging structures with flank dips of $10^{\circ}$ to $25^{\circ}$; here, the lutites in the sequence display well developed axial-plane cleavage. Farther south, folding is gentle, but cross-folding has produced domes and basins; cleavage is well developed in the lutites in this area also. Elsewhere, the formation is tightly and completely folded and overfolded and is cleaved and jointed. The style of folding varies with the amount of sandstone in the sequence. Where sandstone interbeds make up most of the unit, the beds are folded into parallel folds with right-angled crests and troughs from which the lutites have been squeezed (Pl. 3, fig. 2). Where the lutites are dominant, the structures are tight and isolated sandstone beds may be disrupted and rotated.

The only marine fossils found (localities Du510 & Du511) are in the southeast of the Duaringa Sheet area in the west flank of the Thuriba Anticline, where the formation conformably overlies the Oxtrack Formation. The fossils from locality Du511 belong to Fauna IV; the fauna from locality Du510 includes Thamnopora, Cladochonus, and crinoidal material, all commonly associated with Fauna IV. South of Thuriba homestead, in the Monto Sheet area, the Oxtrack Formation is overlain by the Barfield, Flat Top, and Banana Formations, and these four constitute the Blenheim Subgroup in that area. Lithologically, the Boomer Formation closely resembles the Barfield and Flat Top Formations as exposed in cuttings in the Banana to Biloela road, about 4 miles east of Banana in the Monto Sheet area.

It is on these lithological and palaeontological grounds that the Boomer Formation is correlated with the Barfield and Flat Top Formations. In the Duaringa and Saint Lawrence Sheet areas, the Boomer Formation is regarded as an isolated formation at the top of the Back Creek Group, equivalent to part of the Blenheim Subgroup. The formation may be partly younger.

In the type area, the Boomer Formation is unfossiliferous and lies unconformably on Back Creek Group containing Fauna II fossils; south and southeast of the type area it lies unconformably on Rannes Beds and Connors Volcanics, and east of the Boomer Range it overlies the Rookwood Volcanics.

West of the Broadsound Range, the Boomer Formation is structurally conformable on Back Creek Group sediments containing Fauna III and IV fossils; the two units may be separated by a disconformity. The main exposure of Boomer Formation near the Styx River is continuous from the type area; here it is structurally conformable on a much thicker Back Creek Group section than in the type area to the south. The relationship in the Styx River area may be conformable. Recognition of isolated outcrops of the Boomer Formation in the Styx River area is tentative and the relationship to the underlying Back Creek Group is obscured by tight folding and faulting.

To the east, in the Rockhampton Sheet area, the formation is overlain by the upper part of, and possibly interfingers with the lower part of, the Dinner Creek Conglomerate (Kirkegaard et al., 1966).

The Boomer Formation is the youngest Permian unit exposed in the eastern parts of the Duaringa and Saint Lawrence Sheet areas. Its upper limit may be defined by mapping in the Rockhampton Sheet area.

The total thickness of the formation is unknown, because the top has not been seen. The 1250 feet of the type section represents only the lower part.

The environment of deposition was partly and perhaps wholly marine. The provenance of the coarse clastics was to the east, probably in the Rockhampton Sheet area. Marine equivalents of the Boomer Formation were deposited in the main part of the Bowen Basin, west of the Connors and Auburn Arches. Possibly the formation was deposited near the eastern margin of a narrow marine strait, open to the north and south.

BLACKWATER GROUP (= Upper Bowen Coal Measures)

The name Blackwater Group is proposed for the sequence of freshwater sediments recognized throughout the Bowen Basin between the marine Back Creek Group below and the Rewan Formation above, and previously referred to as Upper Bowen Coal Measures. The type area of the group is in and near the Parish of Blackwater on the Central Railway, where three component formations are typically developed: the Rangal Coal Measures at the top, the Burngrove Formation in the middle, and the Fair Hill Formation at the base.

In general, the group consists of: festoon and trough cross-bedded feldspathic and lithic labile sandstone and silty sandstone, containing derived and primary volcanic detritus in places, and abundant fossil wood; calcareous sandstone; dark siltstone interbedded with and grading into sandstone in places; grey-green and white ashstone and cherty mudstone containing well preserved plants; carbonaceous mudstone and coal. Beds and lenses of concretionary sandy and silty limestone are common in parts of the unit. Fossil logs occur at a few horizons which may prove to be marker horizons.

The group is about 1750 feet thick in the type area. It is much thinner to the southwest in the Springsure area, but is thicker in the southeast of the basin, and is up to 6000 feet thick in the northern Bowen Basin.

The Blackwater Group contains abundant fossil plants, including Glossopteris indica, G. browniana, G. angustifolia, G. ampla, G. conspicua, G. communis, G. damudica, G. tortuosa, Cladophlebis roylei, Vertebraria indica, Phyllotheca australis, Sphenopteris lobifolia, Samaropsis sp., and Dictyopteridium sporiferum. These plants indicate an Upper Permian to Lower Triassic age (App. 2). The group may be entirely Upper Permian. In the Springsure area, it contains Permian spores and the overlying Rewan Formation contains Lower Triassic spores.

The Blackwater Group is conformable on the Blenheim Subgroup, the youngest unit of the Back Creek Group. In the type area, the boundary is sharp; the group overlies quartzose to sublabile sandstone (the Garnangarra Sandstone Member) at the top of the German Creek Coal Measures. The boundary is not as sharp north of AFO Cooroorah No. 1 Well, where poorly exposed siltstone and sublabile sandstone of the MacMillan Member is at the top of the German Creek Coal Measures. The base of the Blackwater Group can be extrapolated laterally by reference to marker beds which can be traced along strike on the air-photographs. Isolated small outcrops of the Blackwater Group are difficult to identify.

In the Duaringa Sheet area, the Blackwater Group is overlain by the Sagittarius Sandstone Member, the basal member of the Rewan Formation. The contract is structurally conformable, but is probably disconformable in places where the basal beds of the Sagittarius Sandstone Member contain clasts similar to sediments at the top of the Blackwater Group.

The stratigraphy and petrography of the Blackwater Group and of the formations above and below it are currently being investigated in greater detail (Jensen, 1967). In the northern Bowen Basin, the 'Upper Bowen Coal Measures' as formerly mapped (Malone et al., 1964, 1965) included the Rewan Formation. In the Duaringa area, the Rewan Formation is mapped as a distinct formation overlying the Blackwater Group. The stratigraphic nomenclature used in this Report is compared in Table 2 to those used recently by other geologists.

Table 2 : Upper Permian-Triassic Correlation Chart

| | This Report | | Northern Bowen Basin (Malone, Corbett, & Jensen, 1964; Malone, et al., 1966) | Derrington (1961) | |
|---|---|---|---|---|---|
| TRIASSIC | Clematis Sandstone | | Carborough Sandstone | Clematis Sandstone | |
| TRIASSIC | Rewan Formation | Sagittarius Sandstone Member | Upper Bowen Coal Measures | TAURUS FORMATION | Woodlands Member |
| UPPER PERMIAN | Blackwater Group | (Rangal Coal (Measures ( (Burngrove (Formation ( (Fair Hill (Formation | | | Carnangarra Member MacMillan Member |
| UPPER PERMIAN | Back Creek Group Blenheim Subgroup | (German ( (Creek ( (Coal ( (Measures (------- (Maria ( (Formation | Middle Bowen Beds | Middle Bowen Beds | Crocker Sandstone |
| | | | | | Maria Formation |

The group is mapped without subdivision in the Folded Zone and in several isolated outcrops in the Duaringa and Saint Lawrence Sheet areas: the three formations can be recognized in places in the Folded Zone, but their boundaries could not be mapped in the time available. The group underlies gently rolling plains in the Folded Zone. Soil cover is generally thin and rocks are exposed in shallow gullies. The best outcrops are in rock benches along the banks of the Mackenzie River where it cuts across the Folded Zone. Outcrops of undifferentiated Blackwater Group elsewhere are low soil-covered rises surrounded by deep alluvium in the southwest of the Saint Lawrence Sheet area and in the southeast of the Duaringa Sheet area.

The gross lithology of the group was described in the definition. Measured sections EM9, EM10, EM12, and EM13 (Figs 9-13) illustrate the lithology in the Mackenzie River area. Sections EM12 and EM13 were measured on equivalent strata on opposite sides of an anticline, but are difficult to correlate. It is even more difficult to correlate these four sections with the type sections of the constituent formations of the group, partly because the group is thicker in this area than in the type area.

Sections EM9 and EM10 represent the basal part of the Blackwater Group and do not include any equivalents of the Burngrove Formation. They may represent a very thick equivalent of the Fair Hill Formation. Thickening of the Fair Hill Formation from 460



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feet in its type area to about 1200 feet in this area is possible: the type area is on the Comet Ridge, a basement feature which received relatively thin sedimentation throughout the Permian, whereas the sediments in the Folded Zone were deposited in a rapidly subsiding area. Section EM9, consisting largely of volcanolithic sandstone identical with the sandstone in sections EM10 and EM12, probably includes the basal part of the Blackwater Group in this area. A bed of sublabile sandstone occurs between 480 feet and 500 feet above the base of section EM9 and sandstone containing worm tubes occurs at 270 feet above the base. These rock types are common in the Back Creek Group and uncommon in the Blackwater Group; however, the bulk of the rock types in section EM9 indicate that the section is part of the Blackwater Group.

The stratigraphical positions of sections EM12 and EM13 are not known, and their correlation with sections exposed in the Blackwater area is difficult. Both sections consist mainly of sandstone and silty sandstone with many calcareous sandstone beds and lenses and may be equivalent to the Fair Hill Formation.

The equivalents of the Rangal Coal Measures and the Burngrove Formation can be recognized northeast of Bluff, where they are overlain by the Rewan Formation. Outcrop is poor and the coal seams in particular are poorly exposed. The green cherty mudstone, characteristic of the Burngrove Formation, crops out well and identifies the formation. The Blackwater Group in the southwest of the Saint Lawrence Sheet area is poorly exposed and formation boundaries could not be mapped.

Fair Hill Formation

The Fair Hill Formation is defined here as the sequence of rocks lying conformably on the German Creek Coal Measures and overlain conformably by the Burngrove Formation. The name is derived from Fair Hill homestead, 34 miles northwest of Blackwater, in the Duaringa Sheet area. The type section is in a small gully about 4 miles north of Cooroorah homestead (Grid reference: base, 15000987; top, 15141000) in the Duaringa 1:250,000 Sheet area. The lower half of the unit is not exposed in the type section (Fig. 14) except for the basal 5 feet, but is partly exposed in a creek 1 mile to the north, where gentle folding makes thickness measurements unreliable.

The formation crops out in a north-trending strip about 10 miles west of Blackwater and in the northwest of the Duaringa Sheet area. It has also been recognized in isolated outcrops and drillholes in the Saint Lawrence, Clermont, and Mount Coolon Sheet areas on the western flank of the Bowen Basin. The formation is generally poorly exposed, in a subdued topography.

The formation includes: lithic and feldspathic labile sandstone, in places quartz-rich and approaching sublabile sandstone; siltstone, mudstone, and interlaminated mudstone and fine-grained sandstone; calcareous sandstone grading into sandy limestone; tuffaceous clastic sediments including tuffaceous sandstone, white ashstone, thin green chert beds, and volcanic pebble conglomerate; minor carbonaceous mudstone and coal. The lithology of the top of the formation is illustrated in Figure 14. The sandstone is commonly trough cross-stratified and contains much fossil wood, including logs up to 50 feet long (Pl. 4, fig. 1). Hard calcareous lenses and nodules are scattered throughout the unit and are very abundant in some beds, particularly near the base of the formation. Quartz is much more abundant in the sandstone in the type area at Cooroorah homestead than it is in sandstone of possibly equivalent age in the Bundaleer homestead area, 25 miles to the northeast. Near Bundaleer homestead, quartz makes up 60-70 percent of the grains in some specimens, though it is much less abundant in most. The angularity of the quartz grains indicates little reworking of the sediments. Grey, green, and buff pebbly coarse-grained lithic and feldspathic sandstone, possibly derived from volcanic rocks in part, is the most common arenite. It grades laterally into fine-grained sandstone and siltstone, and into quartz-rich labile sandstone.

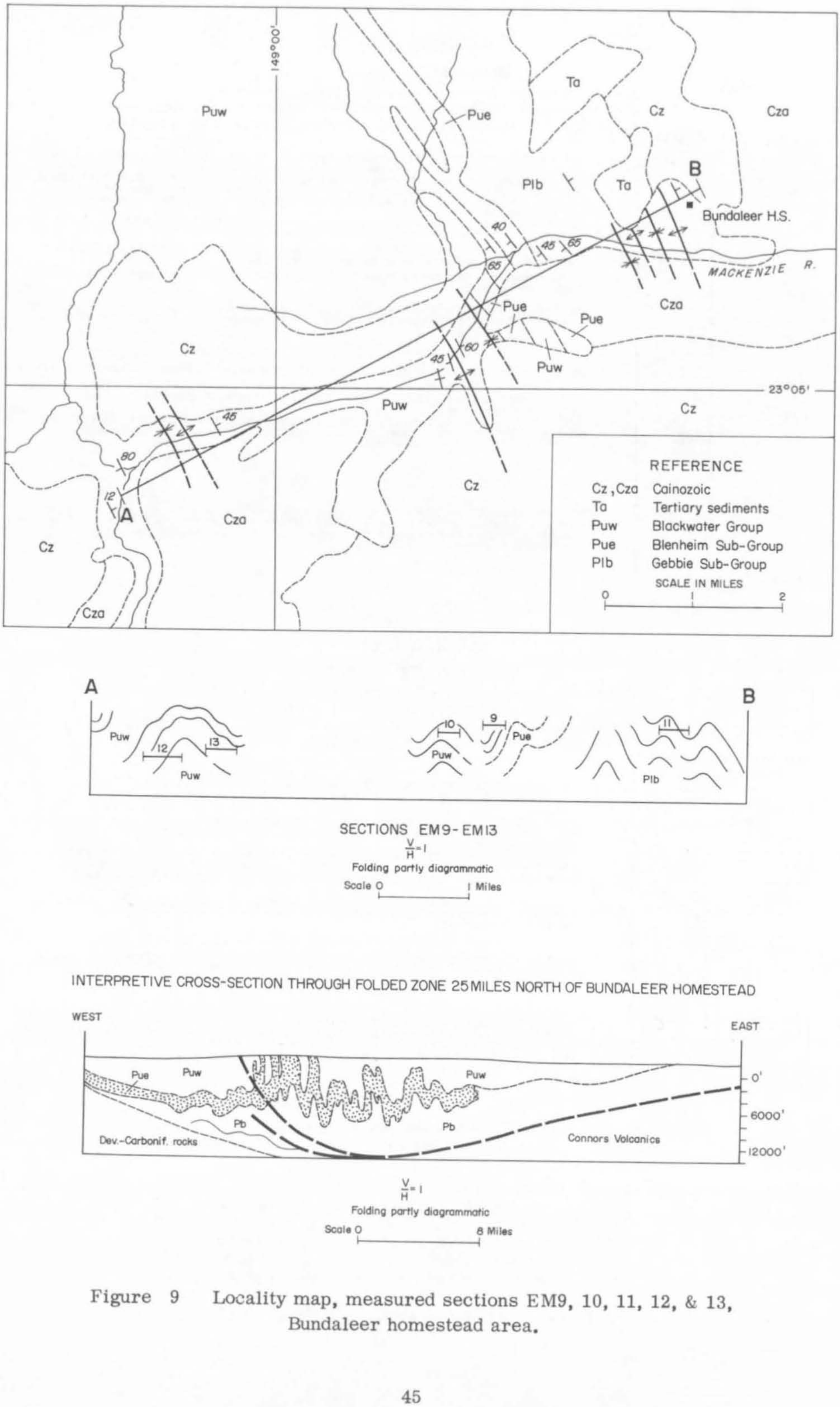
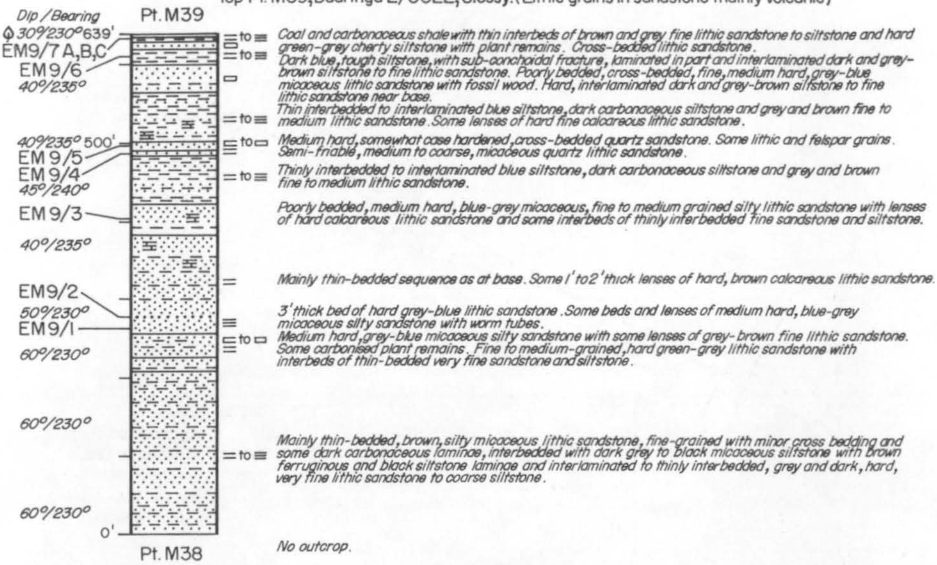



Figure 9 Locality map, measured sections EM9, 10, 11, 12, & 13, Bundaleer homestead area.

## SECTION EM9

BLACKWATER GROUP

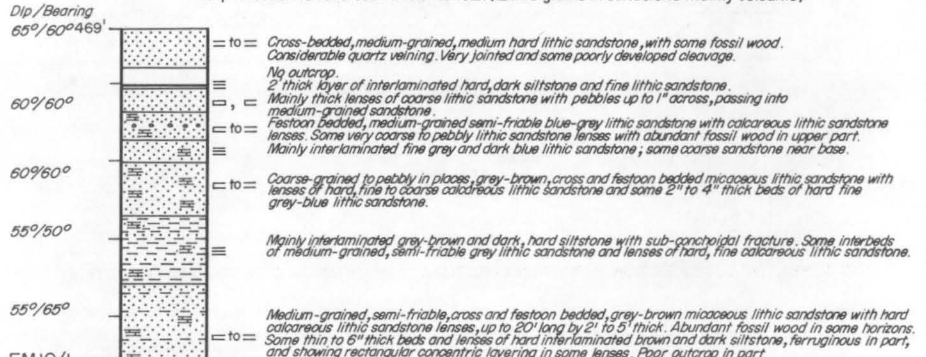
Along south bank of Mackenzie River about 1 mile upstream from Dingo to Junee HS. road bridge. Bottom. Pt. M38, Duaringa 2/5022, Glossy. Top Pt. M39, Duaringa 2/5022, Glossy. (Lithic grains in sandstone mainly volcanic)




## SECTION EM10

BLACKWATER GROUP

Along south bank of Mackenzie River about 1½ miles upstream from Dingo to Junee HS. road bridge. Base. Pt. M40, Duaringa 2/5022, Glossy. Top 220 yds. N.E. of Pt. M40. Base is above gap in outcrop. Top is near trough of syncline. Dip direction is reversed farther to NE. (Lithic grains in sandstone mainly volcanic)




*Note :- Section EM 10 is above EM9. The gap between the two is unknown, but is probably less than 500'*

REFERENCE

| | | | |
|---|---|---|---|
| EM9/1 | *Quartzose volcanic sandstone* | | |
| EM9/2 | *Volcanic sandstone* | | |
| EM9/3 | *Calcareous volcanic sandstone* | ⊄ | *massive bedded* |
| EM9/4 | *Felspathic sub-labile sandstone* | ▭ | *thick-bedded 12" to 40"* |
| EM9/5 | *Sub-labile sandstone* | ⊏ | *medium-bedded 4" to 12"* |
| EM9/6 | *Calcareous claystone* | = | *thin-bedded 0.4" to 4"* |
| EM10/1 | *Calcareous volcanic sandstone* | ≡ | *laminated* |

Figure 10 Measured sections EM9 and EM10.

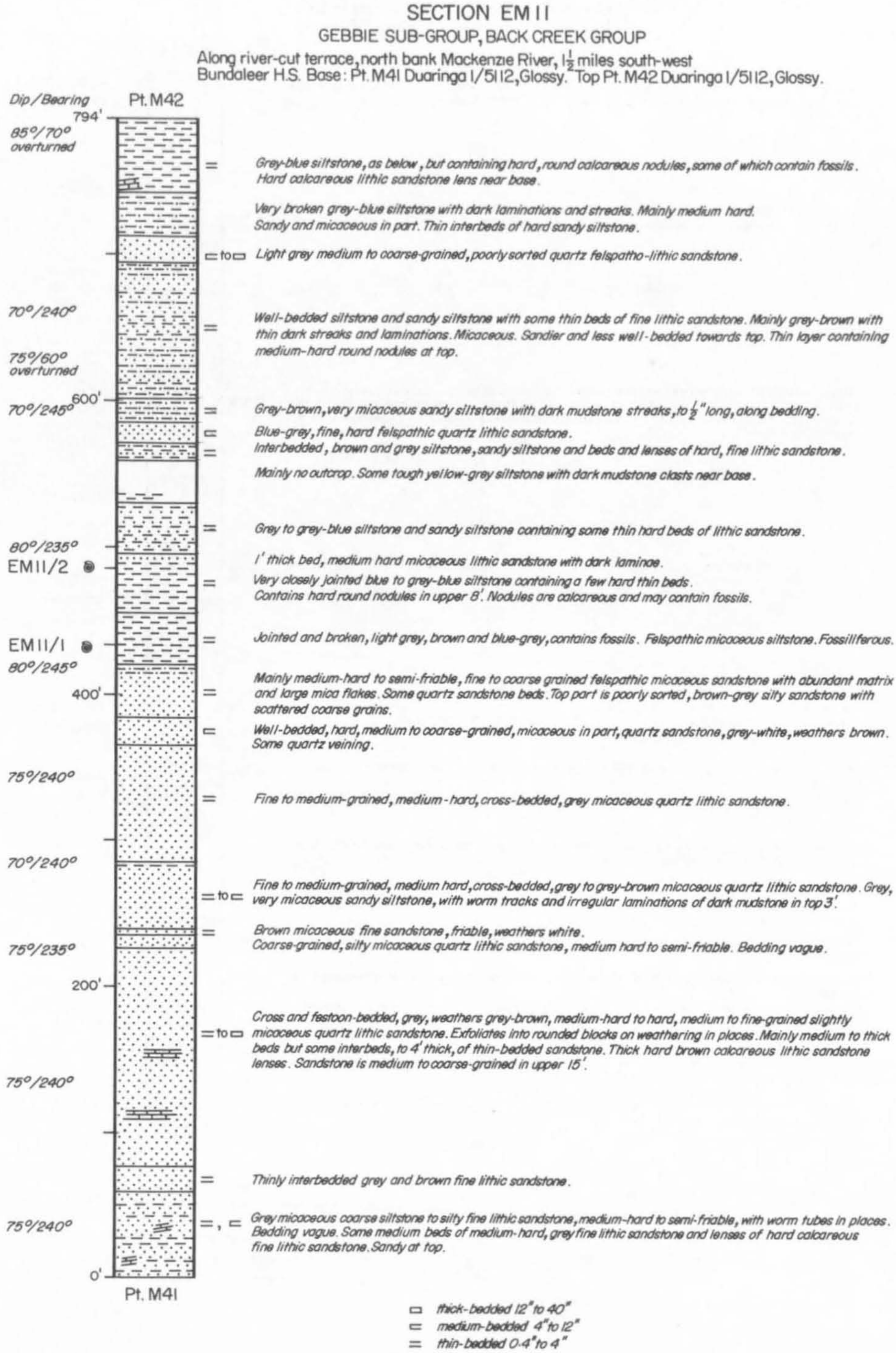



Figure 11 Measured section EM11.

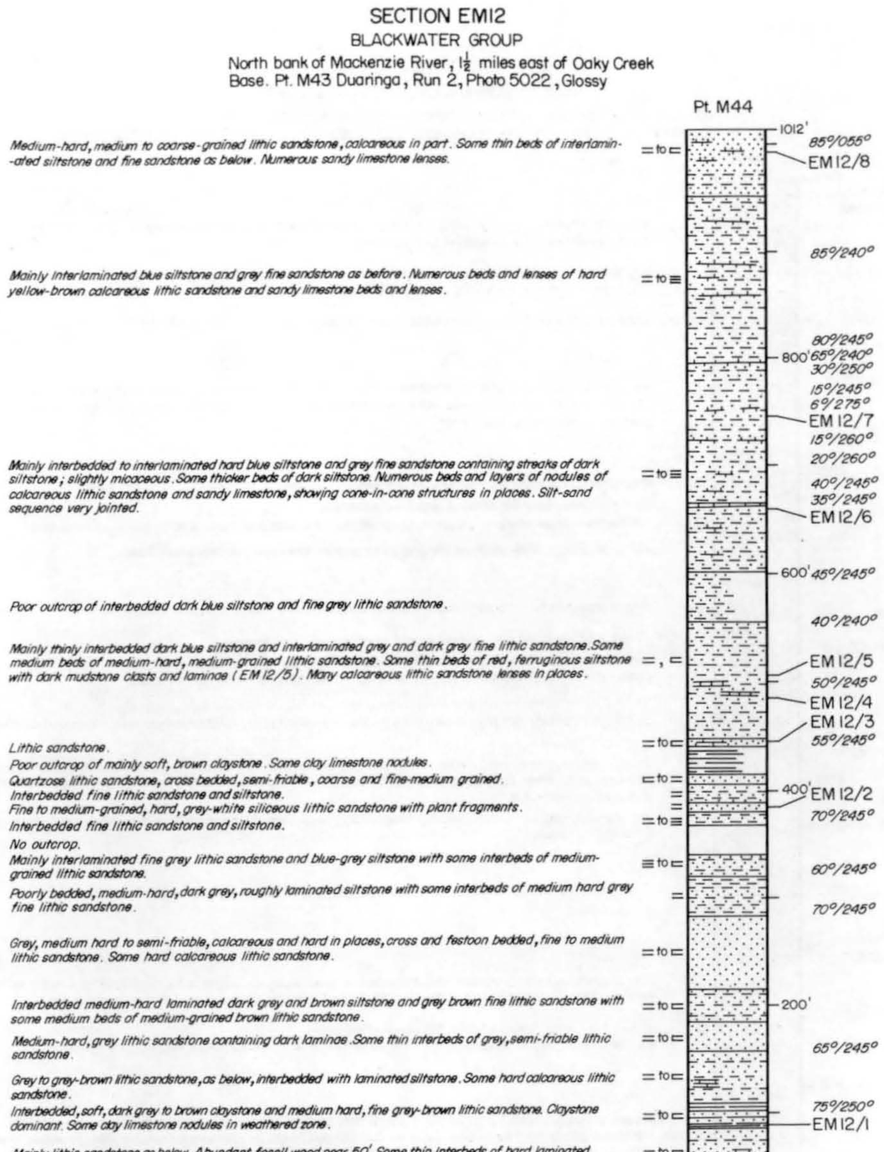



Figure 12 Measured section EM12.


Figure 13 Measured section EM13.

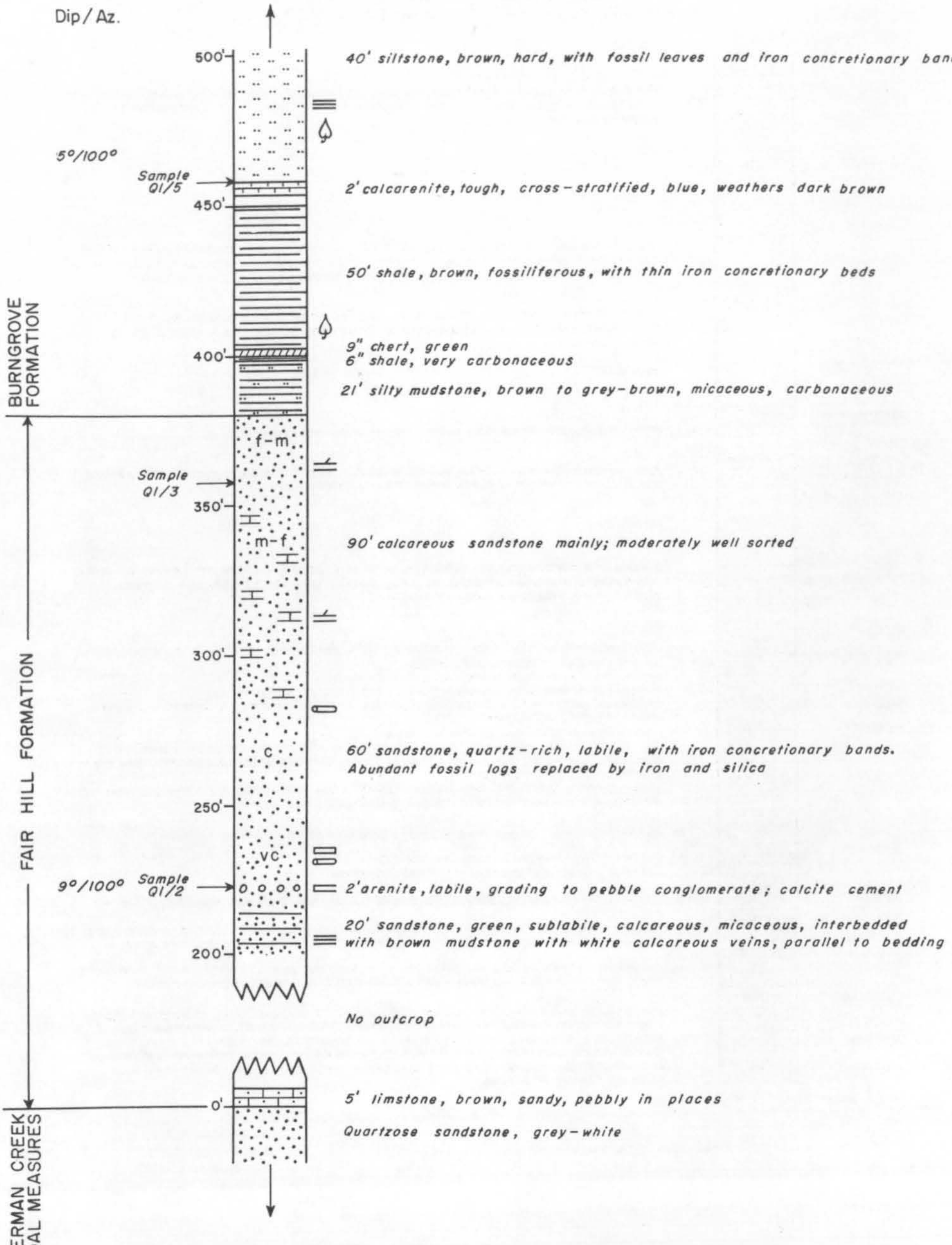



Figure 14 Measured section Q1, type section Fair Hill Formation.

Calcareous sandstone and sandy limestone are common in lenses and beds up to 5 feet thick. The amount of calcite present in the Fair Hill Formation is one of the characteristics which distinguish it from the underlying German Creek Coal Measures.

The lutites in the Fair Hill Formation include dark siltstone interbedded with, and grading into, sandstone, brown to dark grey micaceous and carbonaceous mudstone, and soft brown plant-bearing shale. The unit includes some thin beds of hard green chert and cherty mudstone, which are characteristic rock types of the overlying Burngrove Formation.

Volcanic pebble conglomerate, tuffaceous sandstone, and white ashstone are present in places. These and the rare beds of cherty mudstone may be the result of contemporaneous vulcanism, which may also have supplied some of the feldspathic and volcanolithic grains of the arenites.

The base of the Fair Hill Formation is clearly marked in the type area, where the top of the German Creek Coal Measures is a white quartz sandstone quite unlike any arenite in the Fair Hill Formation. Farther south, there appears to be a transition from the quartz sandstone of the Coal Measures to the quartz-rich labile sandstone of the Fair Hill Formation. Overall, the Fair Hill Formation differs from the German Creek Coal Measures in containing more lithic and feldspathic detritus, abundant fossil wood, and abundant calcite. Worm borings are unknown in the Fair Hill Formation but common in the German Creek Coal Measures. Trough cross-bedding is present in the Fair Hill Formation and planar cross-bedding characterizes the German Creek Coal Measures. The relationships with both the underlying and overlying units appear to be conformable.

In the western part of the Duaringa Sheet area the formation dips gently to the east, south, and west off the Back Creek Group exposed on the Comet Ridge. It is gently folded in places, and flank dips rarely exceed $15^{\circ}$.

The Fair Hill Formation was deposited in a fluviolacustrine environment. The trough cross-bedding, the lenticular bedding, and the abundance of large logs of wood indicate deposition from strong fluvial currents. The abundance of organic matter preserved in the sediments and the absence of any worm borings indicate deposition in fresh water.

The formation contains an abundant fossil flora, but no collections were made. The stratigraphical position above the fossiliferous German Creek Coal Measures indicates an Upper Permian age.

The unit is 460 feet thick in the type section and is approximately 450 feet thick in the Fair Hill homestead area. It thickens to the east, possibly up to 1200 feet in the Folded Zone.

### Burngrove Formation

The Burngrove Formation is defined here as the sequence of rocks, mainly mudstone and siltstone, lying conformably between the Fair Hill Formation below and the Rangal Coal Measures above. The name is derived from Burngrove Creek, which flows through the area of outcrop of the formation 7 miles west of Blackwater. The type section (Fig. 5) is in a small creek about 6 miles north of Cooroorah homestead (Grid reference: base 15251019, top 15421021) in the Duaringa Sheet area.

The Burngrove Formation crops out in a narrow north-trending strip in the western part of the Duaringa Sheet area. It has been recognized in the Folded Zone and in seismic drill holes on the western flank of the Bowen Basin in the Saint Lawrence and Clermont Sheet areas. Relief over the formation is low: the gently dipping rocks crop out in large flat pavements.

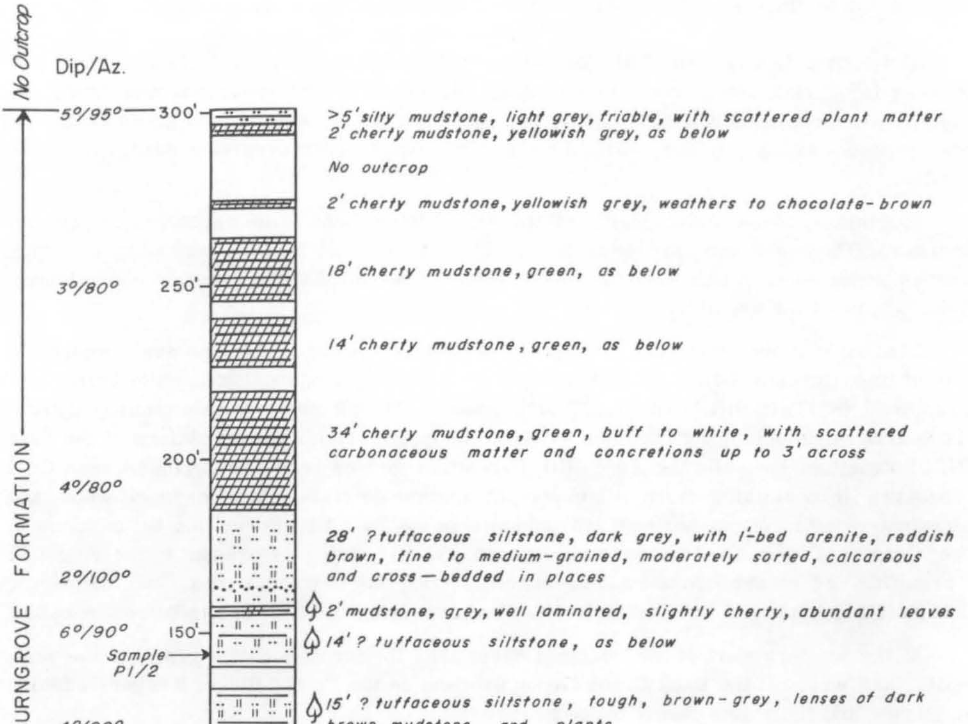



Figure 15 Measured section P1, type section Burngrove Formation.

The lithology is illustrated in Figure 15. It consists mainly of green, yellow, grey, and white cherty mudstone, and dark grey, blue, and brown hard siltstone, siliceous and possibly tuffaceous in part. Interbedded with the mudstone and siltstone are dark grey to black shale, labile sandstone, and calcareous sandstone. The type section includes only a small amount of clastic detritus above silt size: the lack of sand may indicate that the formation was deposited in a local low-energy environment. Elsewhere, the formation includes considerable calcareous sandstone and thinly interbedded to interlaminated dark siltstone and fine-grained buff sandstone.

The sandstone is medium hard, fine to coarse-grained, very well bedded and sorted, and contains abundant macerated and carbonized plant material. It consists of subrounded to rounded grains of vitric tuff and euhedral grains and broken laths of feldspar (mainly andesine), commonly partly replaced by calcite. Euhedral quartz grains constitute 5-10 percent of the rock. Optically continuous calcite cements the grains and may constitute up to 25 percent of the rock, which in hand specimen commonly shows fontainebleau texture. Irregular bands of clay are present in some specimens. The cherty mudstone contains considerable volcanic ash. Irregular lenses of yellow-brown sandy or silty limestone occur in the sequence.

The Burngrove Formation is characterized by the dominance of cherty mudstone and hard siltstone. It is further distinguished from the Fair Hill Formation by the absence of coarse-grained trough cross-bedded labile sandstone and fossil tree trunks.

Regionally the formation is part of a sequence dipping gently east of the Comet Ridge. In places, it is folded, but flank dips rarely exceed $15^{o}$.

The Burngrove Formation was probably deposited during a period of slow sedimentation. The interbedded siltstone and sandstone show delicate interfingering of sand and silt and small-scale load casts and minor slump structures, suggesting deposition in very quiet conditions. The dominance of cherty mudstone reflects the slow rate of supply of coarse clastic sediments. The quiet conditions of sedimentation are consistent with the lack of the coarse clastics, the absence of fossil tree trunks, and the lack of well developed cross-bedding, all of which are characteristic of the underlying Fair Hill Formation. Animal tracks are preserved on an extensive rock pavement 3 miles south of the type section (Pls 4 and 5). Some of the marks may have been made by the fins of bottom-feeding fish dragging on the muddy bottom. The formation was possibly deposited in shallow water near the margin of a freshwater or brackish lake.

Plant fossils are common throughout, and are particularly well preserved in the cherty mudstone. The formation is regarded as Upper Permian because of its stratigraphic position. North and south of the type section it includes more sandstone; it is about 300 feet thick in the Burngrove Creek area but thicker to the north.

Rangal Coal Measures

The Rangal Coal Measures are the topmost unit in the Blackwater Group. The Coal Measures are defined here as the sequence of rocks lying conformably on the Burngrove Formation and overlain, probably disconformably, by the Sagittarius Sandstone Member of the Rewan Formation. The name is derived from Rangal Railway Siding, 4 miles west of Blackwater in the Duaringa Sheet area. The type section is in Deep Creek, 3 miles southwest of Taurus homestead (Grid reference : base, 15280404; top, 15660453). The formation crops out in a north-trending belt of country west of Blackwater and in a small area near Bluff. It has been recognized in drill holes and isolated outcrops in the Saint Lawrence, Clermont, and Mount Coolon Sheet areas on the western flank of the Bowen Basin.

The lithology is illustrated in composite sections compiled from the logs of Utah Development Company drill holes in the Rangal and adjacent areas (Fig. 16). The lithology of the top 235 feet is illustrated in Figure 17, which presents the log of a continuously cored hole drilled by the Broken Hill Pty Co. Ltd 10 miles south of Blackwater. In general the formation consists of mudstone and carbonaceous mudstone, feldspathic and volcanolithic sandstone, calcareous sandstone, carbonaceous shale, and coal seams. The top and base are well exposed in the type section, but the remainder is poorly exposed and gentle folding makes thickness measurements difficult. The type section is up to 700 feet thick.

The formation contains an abundant fossil flora, including most of the species listed in the definition of the Blackwater Group, and is Upper Permian. Spores recovered from well cores and cuttings have been identified as Permian; Triassic spores have been recovered from the overlying Rewan Formation. The Rangal Coal Measures are conformable on the Burngrove Formation and are conformably or disconformably overlain by the Sagittarius Sandstone Member of the Rewan Formation. Their lateral relationships are discussed in the section dealing with the stratigraphy of the Blackwater Group.

The Rangal Coal Measures are poorly exposed. The composite sections (Fig. 17) produced from drilling logs illustrate the gross lithology, thickness, and lateral variation of the various rock types. The unit contains at least two fossil wood horizons: in one, near the base, most of the wood is replaced by silica; in the other, most is replaced by hematite and siderite. These may prove to be important marker horizons. The arenites are mainly feldspathic or lithic labile sandstone grading to sandy limestone. They are grey, cream, brown, rarely green, and commonly very calcareous. The most common rock types in outcrop are hard calcareous sandstone and sandy or silty limestone; the non-calcareous sandstone is friable. The sandstone is mainly fine to medium-grained. It contains beds and lenses of pebbly sandstone and granule conglomerate. Black, dark grey, green, and brown mudstone and carbonaceous mudstone make up about half the unit in some areas. The mudstone is commonly interbedded with sandstone and grades laterally into sandstone. Coal and carbonaceous shale are abundant. The base of the Rangal Coal Measures is placed at the top of the green cherty mudstone characteristic of the Burngrove Formation; this is a fairly sharp boundary in some places but is generally gradational. The upper boundary marks the change from the carbonaceous sediments of the coal measures to the non-carbonaceous, mainly green lithic sandstone and siltstone of the Sagittarius Sandstone Member (Fig. 17).

The Rangal Coal Measures were deposited in a non-marine, probably paludal, environment.

## Triassic

### MIMOSA GROUP

The Mimosa Group is defined here as the sequence of Triassic rocks conformably or locally disconformably overlying the Blackwater Group and unconformably overlain by the Jurassic Precipice Sandstone. The type area is in the Mimosa Syncline in the Baralaba Sheet area. The Mimosa Group consists in ascending order of the Rewan Formation, Clematis Sandstone, and Moolayember Formation, of which the last is absent from the area covered in this Report. The group crops out in the central southern part of the Duaringa Sheet only, though the Rewan Formation has been recognized in seismic shot holes in the Saint Lawrence Sheet area, west of the Folded Zone. Marine macrofossils have not been found; plant fossils suggest a Triassic age. Palynological work in the southern Bowen Basin indicates a Lower Triassic age for the Rewan Formation and a Middle to Upper Triassic age for the Moolayember Formation (Evans, 1964b).

The Rewan Formation is conformable or locally disconformable on the Blackwater Group. The boundary is marked by a major change in lithology from coal measures to mainly 'red-beds' practically devoid of carbonaceous matter. The locus of maximum sedimentation of the Blackwater Group is in the northern Bowen Basin and that of the Rewan Formation is in the east flank of the Mimosa Syncline. Thus, the boundary between the

Blackwater and Mimosa Groups reflects a major climatic change and a drastic change in the locus and environment of deposition, and probably a break in deposition.

Rewan Formation (Isbell, 1955; Hill, 1957)

The sediments in the Duaringa Sheet area now assigned to the Rewan Formation were formerly called the 'Arduran Formation' (Derrington & Morgan, 1959a) and were correlated with the Rewan Formation of the Springsure area. Later, Derrington & Morgan (1959b) abandoned the name 'Arduran Formation', and assigned the sediments to part of their Permian Taurus Formation because the chocolate-brown argillaceous sediments occur 'indiscriminately with green and olive drab coloured sediments' characteristic of the 'Taurus Formation'. The observation is correct; but the incoming of red-brown mudstone and the absence of carbonaceous material have sufficient environmental significance to warrant identification with the Triassic Rewan Formation. The sediments in the Duaringa Sheet area are so similar lithologically and in stratigraphical position to the Rewan Formation of the type area that direct correlation is justified; they are almost certainly continuous below the surface. The correlation is supported by both palynological and palaeobotanical data. The interbedded green lithic sandstone and red-brown mudstone at the base of the Rewan Formation is here called the Sagittarius Sandstone Member and is described below. It is probably equivalent to the 'Lower Rewan Group' of Shell (Queensland) Development Pty Ltd (1952).

The Rewan Formation crops out in the southern half of the Duaringa Sheet area north, east, and west of the Blackdown Tableland and north of Bluff. It erodes readily to form flat or undulating plains which support sparse low scrub and scattered patches of dense brigalow, and are deeply incised by gullies. The formation is best exposed at the base of a Clematis Sandstone escarpment, notably at the heads of Springton, Stony, and Duckworth Creeks. Good outcrops are also present in the Bluff area, a few miles north-northeast of Bluff in Wild Horse Creek, and in a small upper tributary of Charlevue Creek. Bedding trend-lines are visible on air-photographs north of Bluff, where the soil is thin; but generally a deep soil cover prevents the development of a distinctive photo-pattern.

The Rewan Formation is not exposed in the Saint Lawrence Sheet area, but red-brown mudstone was recognized in seismic shot-hole samples near Warwick homestead, less than 1 mile from outcrops of folded Back Creek Group. The formation is possibly separated from the Back Creek Group by an east-dipping thrust fault which is thought to form the western boundary of the Folded Zone.

Soft massive red-brown mudstone is the characteristic, and the most abundant, sediment; it crops out as thick beds, in places over 100 feet thick, notably near the head of Stony Creek. The mudstone contains thin interbeds of green siltstone and green fine to medium-grained lithic feldspathic sandstone, irregular pockets and stringers of light green mudstone, and distinct layers of nodular calcareous concretions with fontainebleau texture. The red-brown mudstone is dominant towards the top of the formation. In the lower part, similar mudstone in beds ranging from a few feet to 20 feet thick is interbedded with varicoloured argillaceous and arenaceous sediments. This lower unit was mapped as the Sagittarius Sandstone Member. Near Bluff, Wild Horse Creek, Tantallon homestead, and Yarrawonga homestead, the Rewan Formation consists of varicoloured sediments, mainly fine to medium-grained friable lithic feldspathic sandstone, in places containing hard calcareous ovoid concretions up to 5 feet in diameter, and siltstone and shale. These sediments are finely interbedded with chocolate-coloured mudstone north-northeast of Bluff in Wild Horse Creek, near Bluff, and at the head of Springton Creek, and probably belong to the Sagittarius Sandstone Member. The sandstone is commonly cross-bedded in units 1 and 2 feet thick; festoon-bedding is present in places, notably in Blackwater Creek south of Yarrawonga homestead. The sandstone contains a few thin beds of intraformational conglomerate containing mud and silt pellets, commonly flattened parallel to bedding, and pebbles of green lithic sandstone.

The Rewan Formation crops out in the limbs of the broad Mimosa Syncline, which strikes north-northwest and plunges south. In the west limb the regional dip is $1^{\circ}$ to $5^{\circ}$, interrupted by small shallow folds; such folds are well exposed south of Yarrawonga homestead, in Blackwater Creek, and northeast of Tantallon homestead. The formation is tightly folded in the east limb of the syncline. Incompetent folding is well exposed at the head of Springton Creek and southwest of Charlevue homestead. The folds are commonly asymmetrical, have wave lengths of 20 feet or less, and are impersistent along strike; they are situated on the flanks of broad, gentle folds. Minor thrusting is common and the rocks are mildly indurated and shear-jointed. The incompetency of the Rewan Formation contrasts with the competency of the Clematis Sandstone, which has adjusted to the underlying incompetent folding by normal faulting with drag against the fault planes. Northwesterly faults on the west flank of the Springton Anticline have brought the Clematis Sandstone against the Rewan Formation; dips up to $70^{\circ}$ in both formations have been recorded near the fault. Folded Rewan Formation is exposed immediately west of Bluff and a few miles to the north and northeast. Outcrop is confined to a few creek sections, but where trends of bedding are visible on air-photographs, structures can be delineated. The folds strike northwest, and are commonly about half a mile broad and 1 to 2 miles long, and some are elongate domes and structural basins. Flank dips are commonly from $20^{\circ}$ to $30^{\circ}$, but range from $5^{\circ}$ to $70^{\circ}$. The folding is best displayed in Wild Horse Creek, and immediately west of Bluff, in Duckworth and Bluff Creeks. North of Wild Horse Creek, the formation is probably preserved only in synclines. The mapped eastern boundary with the Blackwater Group is only approximate, because of poor outcrop. Faulting in the Rewan Formation is minor, and consists of small thrust faults in the tightly folded rocks. Zones of slickensided coarsely crystalline calcite in gently dipping beds in Stony Creek probably represent fault planes.

The Rewan Formation is dominantly a 'red-bed' sequence similar to, and possibly a regional correlate of, the early Triassic Narrabeen Group in the Sydney Basin. The Rewan Formation consists dominantly of red argillaceous sediments devoid of organic matter, with marls and intraformational conglomerate; some of the sediments contain desiccation cracks. Grey-green siltstone and festoon-bedded sandstone with plant remains are interbedded with the 'red-beds'. Geologists of Shell (Queensland) Development Pty Ltd (1952) thought that the chocolate clays were lake deposits. Phillips (in Hill & Denmead, 1960, p. 188) suggests that the chocolate mudstone was derived from an arid or lateritized land surface. Other authors have suggested that the 'red-beds' are aeolian deposits. It is generally accepted that the 'red-bed facies' are non-marine deposits which accumulated under strongly oxidizing conditions. The presence of desiccation cracks and intraformational conglomerate suggests intermittent exposure and shallow-water deposition. The considerable sandstone component of the Rewan Formation is quite immature and probably represents rapid sedimentation with little reworking.

According to Shell (Queensland) Development Pty Ltd (1952), the Rewan Formation in the Springsure Sheet area has a wide range in thickness up to 2000 feet. In the Duaringa Sheet area the thickness also varies; the formation is possibly 2500 feet thick on the western limb of the Mimosa Syncline, but appears to be thinner in the Springton Anticline. It is structurally conformable but probably disconformable on the underlying Blackwater Group. The base of the Rewan Formation is near the Permian-Triassic boundary. Triassic spores were determined by P.R. Evans from shot-hole samples from the Sagittarius Sandstone Member about a mile east of Blackwater, and probable Triassic plants were collected near the head of Springton Creek.

## Sagittarius Sandstone Member

The Sagittarius Sandstone Member is defined here as the basal part of the Rewan Formation in the Duaringa Sheet area. The name is derived from Sagittarius Creek, 1

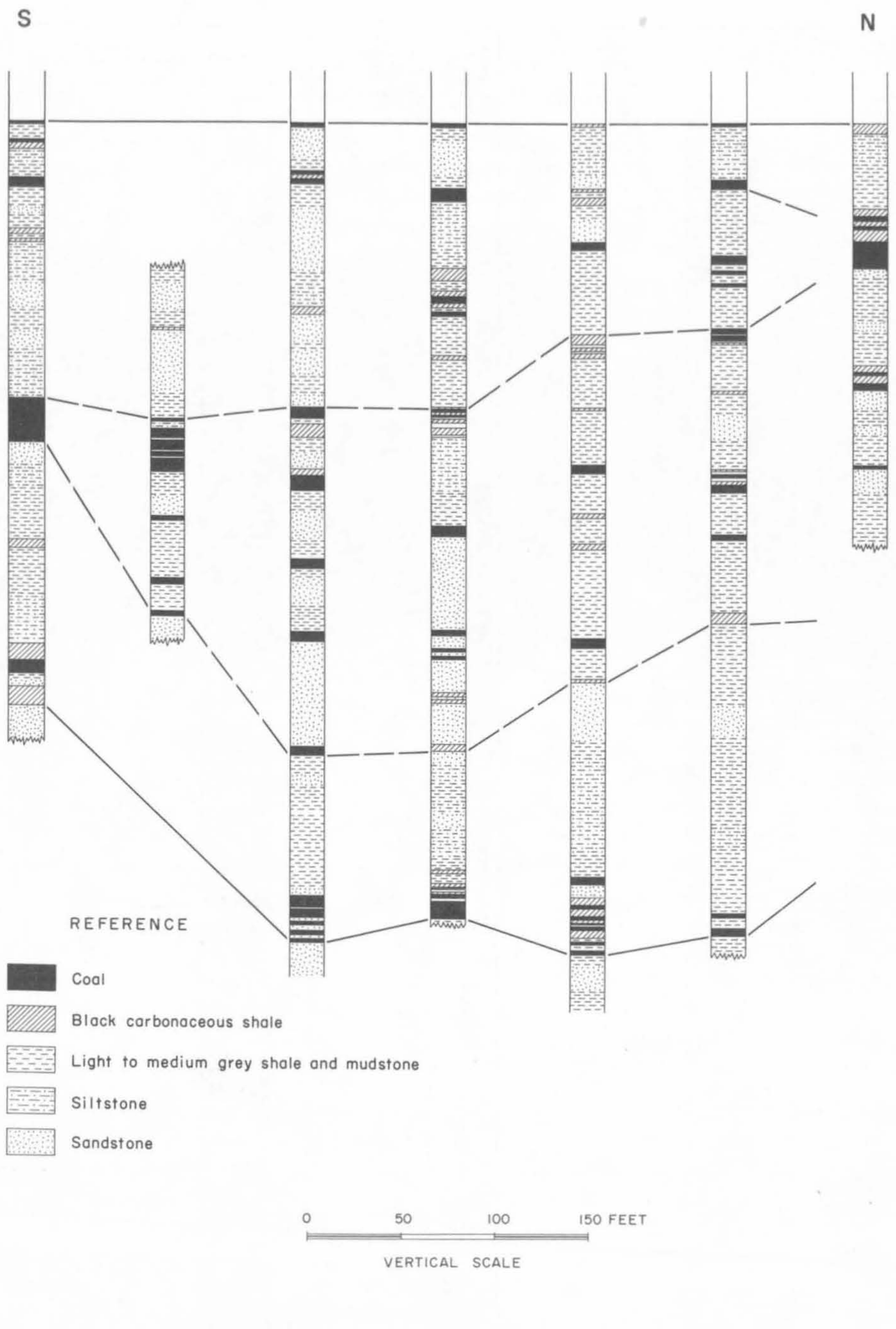



Figure 16 Composite section, Rangal Coal Measures.

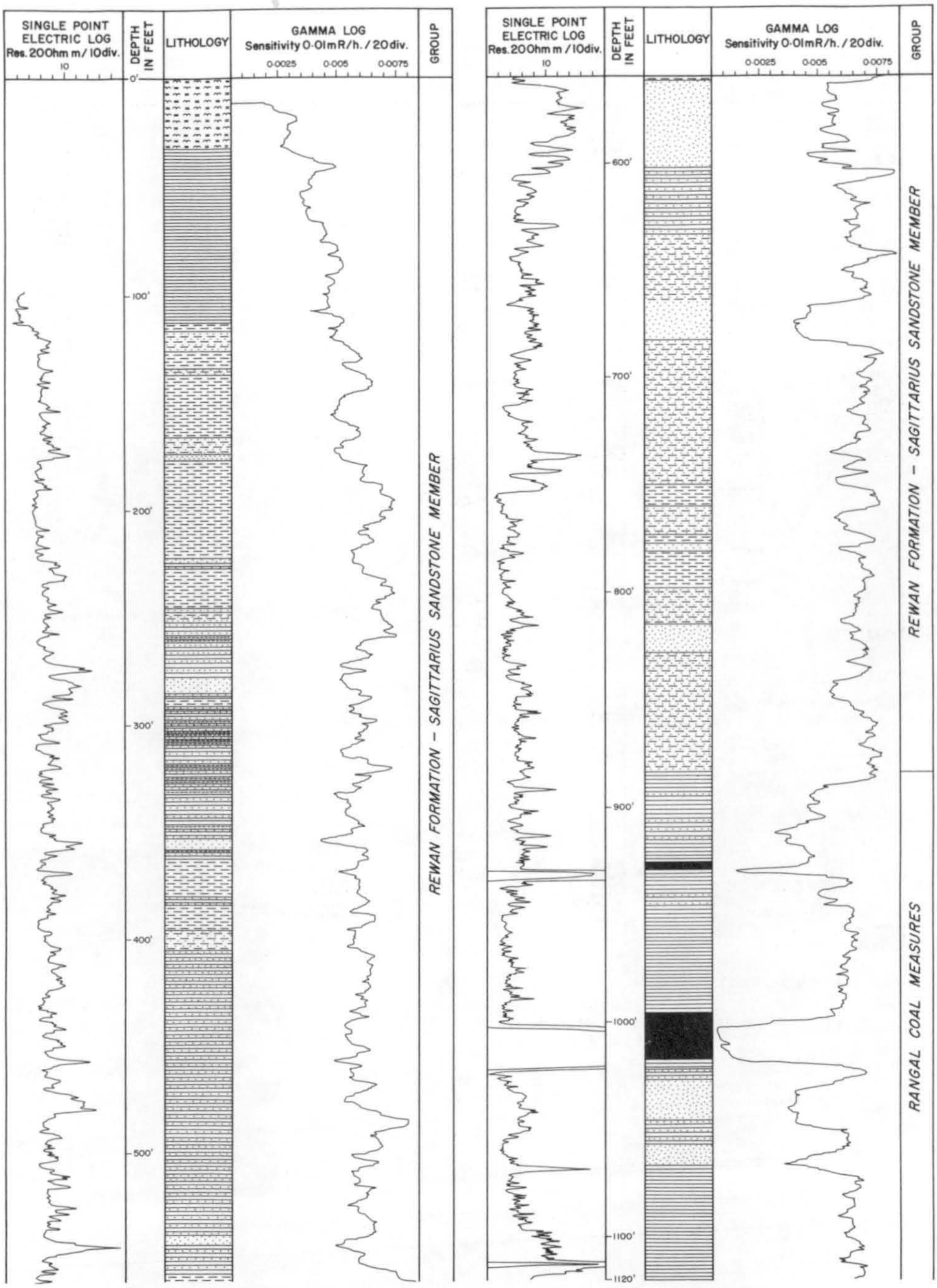



Figure 17 Log of BHP Blackwater No. 1 stratigraphic hole in the Rangal Coal Measures and Rewan Formation.

mile north of Blackwater. The type section is in contiguous stretches of Blackwater, Taurus, and Deep Creeks (Grid reference: base 15660435, top 16300501). The top of the member is concealed in the type section, but is exposed 5 miles to the southeast in Two Mile Creek, at co-ordinates 16730385, Duaringa Sheet area. The member crops out northwest of the Blackdown Tableland. It was not mapped north of Bluff because of tight folding and poor outcrop, but the rock types indicate its presence. Similar rocks crop out in the Springsure Sheet area (Shell's 'Lower Rewan Group', see Mollan et al., 1969) and around outliers of Carborough Sandstone in the northern Bowen Basin.

The member consists mainly of green or grey-green feldspathic and lithic sandstone. The sandstone is medium to coarse-grained and festoon-bedded, interbedded with red-brown, green, and rarely dark grey mudstone. The base of the member is marked in some places by a thin conglomerate containing fragments of shale from the underlying Rangal Coal Measures. Elsewhere it is marked by a zone of thin limestone lenses showing cone-in-cone structure; the member is distinguished from the rest of the Rewan Formation solely on the dominance of sandstone. The lithology of the Sagittarius Sandstone Member is illustrated in Figure 17, which presents the log of a continuously cored hole drilled by the Broken Hill Pty Co. Ltd 10 miles south of Blackwater. The log illustrates the difference in lithology between the Sagittarius Sandstone Member and the underlying Rangal Coal Measures. The top of the member is the base of the lowest thick bed of massive red-brown mudstone in the Rewan Formation.

The member is estimated to be 1000 to 1500 feet thick south of Blackwater. Low-amplitude folding and poor outcrop make measurement of thickness difficult in the type area. A sample from a seismic shot hole located 1 mile east of Blackwater yielded Lower Triassic spores (P.R. Evans, pers. comm.).

<u>Clematis Sandstone</u> (Jensen, 1926)

Jensen (1926) first used the term 'Clematis series' for beds above the 'Upper Bowen' and below the 'Ipswich Beds'. Later authors used the geographic prefix 'Carnarvon' for beds equivalent, at least in part, to beds prefixed 'Clematis'. Whitehouse (1955) discussed the application of the various names (e.g. 'Carnarvon Red Member', 'Carnarvon Sandstone', 'Clematis sandstone') and preferred Clematis Sandstone on grounds of priority and convenience. He designated the type area as the gorge of Clematis Creek in the Roma district, after discussions with Jensen.

The Clematis Sandstone crops out in the Duaringa Sheet south of the Central Railway between 149°E and 149°30'E. It is well exposed in precipitous white or pinkish buff lower cliffs of the Expedition and Shotover Ranges in the west and in cliffs and cuestas of the Dawson Range in the east. The Blackdown Tableland, a densely timbered dissected plateau about 2500 feet above sea level, lies at the northern end of the ranges and consists of Clematis Sandstone overlain in part by Precipice Sandstone. An outlier of Clematis Sandstone south of Bluff forms high cliffs, such as Arthurs Bluff. The outcrop of the Clematis Sandstone extends southwards into the Baralaba Sheet area, where it forms less prominent, though distinct, ranges.

The Clematis Sandstone is essentially a white medium to coarse-grained quartz sandstone with thin beds and pockets of angular granules and pebbles of quartz. Purplish red layers of ferruginized sandstone, a few inches thick, give the rock a banded appearance. The sandstone is micaceous, flaggy, and kaolinitic in places. It contains interbeds of soft thinly bedded light purplish grey micaceous siltstone with plant fragments and soft white kaolinitic micaceous siltstone. The sandstone is commonly thick to medium-bedded, and cross-bedded in units several feet thick. Sets of vertical joints are prominent; one set, striking northwest, can be seen on some air-photographs.

The Clematis Sandstone is preserved in the broad trough of the Mimosa Syncline and on the crests of two broad parallel anticlines in the east limb of the syncline. The west limb of the syncline dips east at angles generally less than $5^{o}$. Flank dips in the folds on the east limb range from $10^{o}$ to $15^{o}$; the folds are readily discernible on the air-photographs because the sandstone beds form cuestas. Steep dips and pronounced slickensides occur in narrow fault zones along the axis of the Springton Anticline. These faults and a few transverse faults formed as the resistant Clematis Sandstone adjusted to tight folding in the underlying incompetent Rewan Formation. The cliff of Clematis Sandstone south of Cooinda homestead is probably a fault scarp, produced by a series of small northwest faults. Several distinct northwesterly lineaments are visible on the air-photographs in areas of outcrop of the Clematis Sandstone; these are interpreted as faults.

The Clematis Sandstone is a mature quartz sandstone which was probably deposited in a shallow fluviatile environment. The sharp contrast with the dominantly red-brown mudstone and labile sandstone of the Rewan Formation probably indicates at least local disconformity. The change probably results from two causes: (1) A change in provenance reduced the supply of volcanic detritus and increased the supply of quartz. The effects of gradually changing provenance are obvious in the Baralaba Sheet area (Olgers et al., 1966), where the complete Rewan Formation is present; there the quartz content of the Rewan Formation increases upwards as the Clematis Sandstone is approached. (2) A change in depositional environment from the rapid subsidence and sedimentation of the Rewan Formation to a slower rate of subsidence and sedimentation permitted greater reworking of the sediments and deposition of a more mature sediment.

The Clematis Sandstone is about 800 feet thick along the western limb of the Mimosa Syncline, but is probably slightly thicker along the eastern limb. In the Reids Dome area of the Springsure Sheet area, the Clematis Sandstone is about 500 feet thick (Mollan, Dickins, Exon, & Kirkegaard, 1969). It thickens to the east and is about 1200 feet thick in the east limb of the Rewan Syncline, and about 1000 feet thick in the Dawson Range (Olgers et al., 1966).

Plant fossils from the Clematis Sandstone in the Springsure Sheet area indicate a Triassic age (Hill, 1957). Only indeterminate plant remains were found in the Duaringa Sheet area. Palynological data on surface and subsurface samples indicate a Middle to Upper Triassic age (Evans, 1964b).

## Jurassic

### Precipice Sandstone (Whitehouse, 1955)

The Precipice Sandstone occurs in a small area in the south of the Duaringa Sheet area on the Blackdown Tableland. It is widespread farther to the south in the Baralaba, Taroom, and Springsure Sheet areas. In these areas, the unit was first referred to as the Bundamba Sandstone (Reeves, 1947), but was later renamed the Precipice Sandstone by Whitehouse (1955). The type area of the formation is in the gorge of Precipice Creek, a tributary of the Dawson River in the Taroom 1:250,000 Sheet area.

Tweedale (in Hill & Denmead, 1960, p. 282) first suggested that the Precipice Sandstone, referred to by him as 'the sandstones of the Bundamba Group of the Great Artesian Basin', appears as an outlier on the Blackdown Tableland south of Bluff. Malone et al. (1963) mapped the whole of the tableland as Clematis Sandstone, mainly because no convincing evidence could be found in the areas accessible to them to suggest that there was an unconformity between the lower and upper sandstones in the tableland. However, photo-interpretation of the inaccessible southern part of the area strongly suggested unconformity. Later work (Olgers et al., 1966) along the southern margin of the tableland, which could be reached from the Baralaba Sheet area, confirmed angular unconformity between the lower and upper sandstones; the upper sandstone is now regarded as Precipice Sandstone. It is lithologically similar to the type Precipice Sandstone.

The Precipice Sandstone is essentially a white medium to coarse-grained thick-bedded cross-stratified kaolinitic quartz sandstone; in places it is very coarse-grained and poorly sorted. Thin interbeds of white soft thin-bedded micaceous siltstone occur throughout.

South of Bluff, the boundary between the Precipice and Clematis Sandstones is about 200 feet below the top of the scarp at the base of strongly jointed cliff-forming sandstone (Pl. 5, fig. 2). The boundary is more distinct along the southern margin of the tableland, where the horizontal Precipice Sandstone unconformably overlies the Clematis Sandstone in the truncated Shotover Anticline.

The Precipice Sandstone, which is about 200 feet thick in this area, was laid down by swiftly flowing streams. It is of Lower Jurassic age (Evans, 1964a).

## Cretaceous

Styx Coal Measures (Dunstan in Walkom, 1915)

The Styx Coal Measures were named the Styx Series by Dunstan (in Walkom, 1915). Rands (1892) described them, after the discovery of coal in 1886 and subsequent prospecting. David mapped the formation in detail before 1900; his work is unpublished, but his maps and sections are held by the Geological Survey of Queensland.

The Styx Coal Measures crop out in a north-trending belt, 30 miles long by about 6 miles wide, extending south from Saint Lawrence to near Tooloombah Creek. The western margin is marked by a line of east-sloping cuestas; the rest of the belt underlies plains, where outcrop is rare. Vegetation consists of light scrub and scattered patches of dense brigalow.

The lithology of the formation is known from the Bowman and Ogmore shafts and from diamond drill holes sunk by the Queensland Mines Department between 1948 and 1951 in the Tooloombah Creek area southwest of Ogmore (Morton, 1955). The following descriptions are based on Morton's work.

The Styx Coal Measures consist mainly of fine-grained grey sandstone and shale, either interlaminated or in thick lenses. Some thin beds of calcareous sandstone are present. Distinctive green sandstone is common; it consists of grains of quartz, chert, and shale, the green colour being due to a green hydromica in interstices between the grains. Nine coal seams were noted in the sequence during the drilling.

Some drill holes that penetrated the underlying Permian sediments revealed a pebble conglomerate at the base of the Styx Coal Measures. The basal sandstone cropping out on the cuestas along the western margin is a light-coloured medium-grained cross-bedded pebbly quartz sandstone, tending to pebble conglomerate in places.

The lithology of part of the Coal Measures near the northern limit is illustrated in Figure 18, a vertical column drawn by David to represent the sequence in the Broadsound No. 1 Shaft and bore. The shaft is shown on the map by crossed hammers, about 3 miles east-southeast of Saint Lawrence, but is now inaccessible. The vertical column shows an angular unconformity at 47 feet; the upper part was referred to the 'Desert Sandstone Series' by David and is probably Tertiary.

The formation dips generally eastwards at about 5°. It is unconformable on the Back Creek Group and is faulted against it along its eastern boundary. The Styx Coal Measures are crumpled and faulted for some distance west of the fault, which is probably a high-angle reverse fault, east block up. The boreholes which penetrate Permian sediments indicate that the Styx Coal Measures were deposited on an irregular surface, deepening progressively towards the faulted eastern boundary.

The Styx Coal Measures are dominantly freshwater sediments; but several species of microplankton have been discovered at one horizon in the sequence (Cookson & Eisenack, 1958). The formation was probably deposited on a coastal plain on to which the sea encroached at times. This region lies on the axis of a major Permian synclinorium. The drilling in the Tooloombah Creek area revealed a maximum thickness of 1270 feet, but the unit is probably much thicker to the east. Walkom (1919) described a Lower Cretaceous flora from the Styx Coal Measures. Spores indicate a Lower Cretaceous, approximately Albian, age (Cookson & Dettmann, 1958).

A small area of Styx Coal Measures was mapped in the Duaringa Sheet area, 9 miles northwest of Redbank homestead. The main rock is a brown friable pebble conglomerate containing plants. The pebbles are mainly indurated siltstone similar to the siltstone of the Rannes Beds, which are exposed to the west. Some sandstone, siltstone, and shale overlie the conglomerate. Outcrop is generally poor. Plant specimens identified by Mary E. White (App. 2) include two species of Taeniopteris and one of Cladophlebis: all three species are found in the Styx Coal Measures, with which these rocks are correlated. The pebble conglomerate at the base of this sequence is probably of local derivation.

Siltstone and coarse-grained quartz sandstone containing well preserved fossil wood on Wild Duck Island, on the northern margin of the Saint Lawrence Sheet area, was considered by White & Brown (1963) to be a possible correlate of the Styx Coal Measures.

## Cretaceous-Tertiary

Scattered outcrops of acid to intermediate flows, pyroclastics, and minor intrusives were mapped as Cretaceous or Tertiary volcanics.

These rocks crop out mainly in the Saint Lawrence Sheet area in the Connors and Broadsound Ranges, where they form cappings on the tops of the hills; they generally produce rough boulder-strewn surfaces, commonly bounded by cliffs, and steep hills. Patches of dense scrub grow on the volcanics. West of the ranges, the volcanics form rugged broken hills, commonly circular or oval.

The only outcrop in the Duaringa Sheet area is east of Craigilee homestead, where a complex of plugs, flows, and dykes forms a steep-sided high area, moderately dissected, with many peaks and rocky prominences.

Rhyolite and rhyolitic agglomerate make up about 90 percent of the outcrop in the Saint Lawrence Sheet area. The remainder includes dacite, toscanite, trachyte, and tuff.

The rhyolite is commonly a pink, pale green, or buff very fine-grained rock. It generally shows flow banding, either smooth or highly contorted, and is saccharoidal and vesicular in places. The rare porphyritic varieties contain small phenocrysts of quartz, potash feldspar, and biotite, commonly aligned parallel to flow banding. Contorted flow-banded rhyolite is commonly associated with agglomerate containing boulders of similar material, whose matrix is a fine-grained massive rhyolite. Fine-grained light-coloured tuff, containing bombs and fragments of rhyolitic lava in places, is associated with the agglomerate.

The Cretaceous/Tertiary volcanics include flows and plugs of grey or cream massive porphyritic dacite. The phenocrysts are mainly plagioclase, up to 3 mm long, and less commonly quartz and biotite. Flow banding is less common in the dacite than in the rhyolite, but in some places is well developed.

The trachyte is generally a pink to grey porphyritic rock containing phenocrysts of potash feldspar; flow banding is well developed. The toscanite is a very fine-grained dark grey porphyritic rock containing phenocrysts of plagioclase, potash feldspar, and quartz.

The volcanics east of Craigilee homestead are a complex mass of acid to intermediate volcanics including plugs, thick flows, and radiating dyke systems, which are unconformable on or intrusive into Carboniferous and Permian rocks. The volcanics are apparently unfolded. They were deposited on an uneven land surface, and consequently vary greatly in thickness.

These rocks are regarded as being part of widespread Cretaceous-Tertiary volcanic activity of this part of Queensland, though the only direct indication of age is that they lie on Triassic and older rocks; but similar activity can be reliably dated as Tertiary in the Clermont Sheet area.

## Tertiary

Tertiary rocks were mapped as three informal units: sediments (Ta), sandstone breccia (Td), and basalt (Tb).

### Sediments (Ta)

Dunstan (1913) mapped Tertiary sediments in the Duaringa area as the 'Nerang-Duaringa Series'. Reid & Morton (1928) used the name 'Duaringa-Emerald Series' for Tertiary and post-Tertiary rocks in central Queensland. The name 'Duaringa Formation' was used on the Geological Map of Queensland (Hill, 1953) for sediments of Tertiary age. Laing (1959) used the name 'Junee Formation' for sediments in the Junee homestead area which he assigned to the Jurassic but which are now regarded as Tertiary. No formal names are used on the maps accompanying this Report.

The Tertiary sediments crop out in a broad belt trending northwest from the southeast corner of the Duaringa Sheet area. This belt splits into two near Dingo; the eastern belt is adjacent to the Isaacs and Mackenzie Rivers, and the western trends northwest from Bluff. The Tertiary sediments are extensive in the southwest corner of the Duaringa Sheet and form many outliers north of Arduran and Galcathoa homesteads. They occur as a few outliers east of the Mackenzie and Dawson Rivers.

The Tertiary sediments commonly form tablelands, generally less than 200 feet high, but locally, northwest of Duaringa, about 400 feet high. The tablelands are capped with a hard zone of lateritized sediments which forms rocky cliffs; the lower slopes are scree-covered and commonly thickly timbered. Sand and red lateritic soil on top of the tablelands support fairly dense timber.

Unlateritized Tertiary sediments are poorly exposed and consist mainly of unsorted sandy gravel, pebbly quartz sandstone, and silty clay; the coarser sediments are usually well lithified. Sandstones include soft off-white medium-grained micaceous clayey quartz sandstone and buff fine-grained cross-bedded sandstone. In places, such as north of Junee homestead, vertical tubes filled with dark silt penetrate unsorted gravelly sandstone normal to bedding and probably represent worm burrows.

The sediments are known from a few bores. Dunstan (1901a) recorded 600 feet of clay, shale, and oil shale in the Duaringa Bore. Ball (1928) described outcrops of green and brown fissile oil shale in the Dawson River, about 14 miles south of Boolburra. Reid (1939b) recorded about 30 feet of diatomaceous earth 6 miles northwest of Junee homestead. Resin-bearing shale was also found by Dunstan (1916c).

The lack of large exposures of the sequence and the lateritization of the upper part preclude study of bedding features. In a few places cross-bedding was observed, notably along the lower slopes of the tablelands north of Junee homestead. The top 20 to 30 feet of most outcrops are lateritized and, because of the relative hardness of the laterite, are well exposed.

The Tertiary sediments are unconformable on Permian and Triassic rocks, and on older rocks in the eastern half of the area. The sediments are covered by superficial deposits, which commonly include reworked laterite and reworked Tertiary sediments.

Dip slopes of less than $5^{o}$ are readily distinguished in the tablelands; regionally, when plotted from air-photographs, broad structures can be discerned, with slopes commonly striking parallel to present drainage. The structures may be controlled by depositional dips in the Tertiary sediments; they may parallel a laterite profile developed on an undulating surface; or they may be folds, though this is unlikely. Lack of bedding in outcrop prevents correlation of surface slopes with the internal structure of the beds.

The sediments are probably lacustrine and fluviatile, laid down on an uneven land surface. Their original distribution was probably limited only by the main ranges, the Gogango, Boomer, and Broadsound Ranges in the east and the Dawson and Expedition Ranges and Blackdown Tableland in the south. Basalt flows are interbedded with the sediments; some sediments probably accumulated in lakes formed where basalt flows dammed the streams.

The thickness of the sediments is probably very variable. Dunstan (1901a) reported at least 600 feet in the Duaringa Bore, and there are 200 to 300 feet in the tablelands immediately west of the Dawson, Mackenzie, and Isaac Rivers. They are thickest in the Duaringa Basin, west of the line of the Isaac, Mackenzie, and Dawson Rivers, where a seismic survey (Robertson, 1961) indicates thicknesses up to 3500 feet.

Fossil fish remains from the clay and shale in the Duaringa Bore (Dunstan, 1901a) were assigned to the Oligocene by David (1932). Hills (1934), after examining other fossil fishes from this bore, reported that 'it is possible to state only that they are Tertiary'. Laing (1959) regarded the sediments near Junee homestead as Jurassic because 'Tertiary basalt appears in places to lap against scarps formed of Junee Formation and in other places to overlie it'. This relationship was not observed during the present survey.

Sandstone Breccia (Td)

Derrington & Morgan (1959a) were the first to note the presence of the breccia. They called it the 'Duckworth Formation' in unpublished reports correlating it with the Triassic Clematis Sandstone. Later work by Derrington & Morgan (1959b) proved the breccia to be much younger, and they assigned it to the Upper Tertiary. The name 'Duckworth Formation' is not used in this Report.

The main area of outcrop of sandstone breccia is between Blackwater and Bluff, extending for several miles north and south of the Central Railway. The breccia is well exposed in low hills west and northwest of Bluff, and also crops out in isolated foothills on the eastern side of Arthurs Bluff and east of the Dawson Range, near Charlevue and Cooinda homestead. It commonly forms low timbered hills and cuestas which give a dark stippled tone on air-photographs. The breccia is well exposed in the hills; in the gently undulating country north of the Central Railway, exposures are limited to shallow breakaways and creek banks.

The breccia consists of large blocks and slabs, 10 to 20 feet across, of medium to coarse-grained cross-bedded quartz sandstone, set in an unsorted matrix of boulders, gravel, and grit of the same sandstone. The sandstone blocks are irregularly tilted in places; in others they are so arranged that thick bedding is roughly continuous through adjacent blocks. The matrix is commonly lateritized.

The sandstone breccia unconformably overlies the Rewan Formation and appears to interfinger with other Tertiary sediments; this is very noticeable in the area between the Bluff-Jellinbah road and the Central Railway. In low hills immediately south of Bluff the breccia is overlain by lateritized Tertiary sediments. The air-photographs reveal sloping surfaces, notably south of the Central Railway, which appear to be dip-slopes, dipping at $5^{o}$ to $10^{o}$ and striking northwest. When examined on the ground, the slopes were seen to be parallel to the bedding in the blocks of sandstone. The dips are probably depositional.

The sandstone breccia is a subaerial deposit of restricted extent. It is derived almost totally from the Triassic Clematis Sandstone and is closely related to the present outcrop of this formation. It represents a remnant piedmont or coarse scree. The large blocks of resistant sandstone have moved only short distances; the Clematis Sandstone was undercut by erosion of the underlying soft Rewan Formation, allowing sandstone blocks to collapse almost in place. The deposit was preserved by burial under younger Tertiary sediments; the breccia is now being reworked where this cover has been removed. The unit varies in thickness; Derrington & Morgan (1959b) cite an approximate thickness of 50 feet; in places it is about 100 feet thick. No fossils have been found, but the breccia antedates the Tertiary laterite and is probably Tertiary.

Basalt (Tb)

Basalt crops out in several widely scattered areas. The largest outcrops are near Comet Downs homestead, Raby Creek homestead, a few miles southwest of Duaringa, in the west of the Saint Lawrence Sheet area, and near May Downs homestead. Small outcrops are scattered over the western half of the Duaringa Sheet area. An outlier lies on the Blackdown Tableland at an elevation of about 1500 feet. The basalt weathers to a black clayey soil and generally forms grassy downs.

Most outcrops are of fine-grained basalt containing aggregates of olivine phenocrysts; some are of vesicular and amygdaloidal basalt. Derrington & Morgan (1959a) record medium-grained basaltic tuffs.

Southwest of Duaringa near the base of Mount Sirloin and near May Downs homestead basalt flows are interbedded with Tertiary sediments. The basalt is generally less than 20 feet thick; however, Derrington & Morgan (1959a) reported flows with a cumulative thickness of 110 feet near Kenmore homestead.

Basic plugs, sills, and dykes, mapped at a few places, were included with the Tertiary basalt. Mount Beardmore, about 6 miles northeast of Rookwood homestead at the head of Balcomba Creek, is a small plug of nepheline basalt (Dunstan, 1901a). Derrington & Morgan (1959b) reported dykes and sills of medium to coarse-grained basic rocks in the Minnie Creek/Cooroorah homestead area and suggest that they are associated with the basaltic vulcanism.

The basalt is correlated with the widespread basalt sheet in the Emerald, Springsure, and Clermont Sheet areas. It is regarded as Tertiary because it is interbedded with Tertiary sediments. Isotopic age determinations on five samples of Tertiary basalt from the Baralaba Sheet area give ages of 20 to 25 million years (Harding, 1966).

## Cainozoic

Piedmont deposits (Czp) of sandy gravels containing rounded and subangular boulders and blocks of Clematis Sandstone cover the lower slopes of hills of Clematis Sandstone. The deposits are widespread south of Bluff and southeast of Blackwater, where they also include reworked Tertiary sandstone breccia.

Undifferentiated Cainozoic (Cz) includes sand, alluvium, and reworked Tertiary sediments and laterite. These superficial deposits cover much of the western half of the area, and small areas in the eastern half. The deposits form plains in interfluve areas and support thick tree cover, including dense stands of brigalow. Black heavy-textured soil is developed in places; elsewhere they produce light sandy soils and sand cover.

Wide belts of alluvium (Qa) are present along the courses of the Connors, Isaac, Mackenzie, Dawson, and Fitzroy Rivers; mangrove swamps and alluvial flats are developed along the coast. The thickness of alluvium varies from place to place. It is up to 100 feet thick in parts of the Fitzroy River valley, east of the junction with the Mackenzie and Dawson Rivers. A water bore 4.5 miles east-northeast of Separation homestead penetrated 275 feet of alluvium without reaching solid rock. The Cainozoic sediments probably have an average thickness of less than 50 feet.

### Laterite

Remnants of a laterite profile are widespread in the area. They constitute most of the top 20 to 30 feet of the dissected tablelands in the Duaringa and Saint Lawrence Sheet areas, west of the ranges, and crop out in smaller areas east of the ranges. The limits of the laterite are usually steep scarps in which the entire profile is exposed, as on Junee Holding and west of the Dawson and Mackenzie Rivers; in some places, the laterite has been progressively levelled off, zone by zone, until the underlying rocks are exposed.

The laterite developed mainly on Tertiary rocks, probably because these covered much of the area during lateritization. It also developed on igneous rocks, mainly ultrabasics, in the northeast of the Duaringa Sheet area and southeast of the Saint Lawrence Sheet area. Much of this laterite has been stripped off and reworked. The lower part of the profile was seen in a few places, grading down into deeply weathered serpentinite.

A complete laterite profile developed on granodiorite is preserved south of the Fitzroy River, north of Redbank homestead; aplite and other veins can be traced from the granodiorite into the laterite.

The profile is about 300 feet above sea level near Duaringa, and 725 feet above sea level 12 miles to the northwest. Since it is apparently continuous, this difference in elevation suggests that either the laterite was developed on a sloping surface, or the area has since been warped. The laterite profile on serpentinite near Marlborough has been displaced by faulting. The laterite probably formed during the Upper Tertiary.

## IGNEOUS INTRUSIONS

Igneous intrusions crop out as small separate bodies in the east of the Duaringa and Saint Lawrence Sheet areas. The largest exposures of intrusive rocks are around Marlborough. Isotopic ages have been determined for some of the intrusions (Table 3). They are described below in chronological order.

### Serpentinite (Pzs)

Serpentinite crops out mainly in the southeast corner of the Saint Lawrence and the northeast corner of the Duaringa Sheet areas as a relatively narrow belt trending northeast from Mount Slopeaway and as a larger block south of Marlborough. It forms high, steep-sided, sharp-crested ridges with light timber cover; grass trees (*Xanthorrhea*) are common. The vegetation is dense on lateritized serpentinite. The serpentinite is deeply weathered and fresh rock can be obtained only from the base of the ridges.

The serpentinite is massive except near contacts, where it is schistose, and was originally dunite, harzburgite, or lherzolite. Antigorite is the dominant serpentine mineral; it is generally fibrous but in places bladed. Chrysotile, in fine veins or intergrown with antigorite, and bastite are common. Unaltered pyroxene and olivine are rare, but the boundaries of the original olivine grains are generally recognizable. Tremolite, probably of metamorphic origin, has been noted in some samples. Blocks of microdiorite are included within the serpentinite in places.

Many of the contacts between serpentinite and adjacent rocks are normal faults, some of which have displaced the Tertiary laterite. The belt trending northeast from Mount Slopeaway dips steeply to the southeast and the contact with the Carmila Beds appears to be faulted; the serpentinite is sheared parallel to the contact. A siltstone of the Carmila Beds in contact with the serpentinite is slightly metamorphosed, but this could have been caused by small gabbroic intrusions nearby.

On the Port Clinton Sheet area, the serpentinite is a gently dipping thin sheet in places, and the contacts with the underlying metamorphics are probably low-angle thrust faults.

The contact between the serpentinite and the Upper Permian intrusion near Marlborough is obscure. Basic hornfels occurs near the contact, but the highest metamorphic grade is not everywhere closest to the granite. The hornfelsing was possibly caused by intrusion of the serpentinite into the Lower Palaeozoic metamorphics; subsequent intrusion in the Upper Permian disrupted the earlier contact and produced some retrograde metamorphism (Kirkegaard et al., 1966).

The age of the serpentinite is not known. Hill (1951) considers the Queensland serpentinites to be associated with a Middle Devonian orogeny. The Marlborough serpentinite was possibly emplaced at depth about that time but moved again, probably in the solid state, during the Lower Permian. It was intruded by high-level granite and granodiorite in the Upper Permian. The emplacement of the serpentinite is discussed in detail in Kirkegaard et al. (1966).

## Urannah Complex (C-Mr)

The name Urannah Complex was introduced by Malone et al. (1966). The type area is on Urannah Station in the southeast of the Bowen Sheet area. The complex includes acid, intermediate, and basic plutonic and hypabyssal rocks and represents several phases of intrusion.

A belt of outcrop extends continuously from the type area into the northern part of the Saint Lawrence Sheet area; here the complex consists of granite, adamellite, tonalite, microgranite and microdiorite, and dykes of microdiorite, andesite, and dacite. The main rock type is pink medium to coarse-grained granite containing large feldspar phenocrysts in places. The adamellite and tonalite are similar in texture to the granite. The microgranite and microdiorite are probably finer phases of the granite and tonalite. The dykes and some small microdiorite masses probably represent different phases of intrusion. Dykes, a few inches to 2 feet wide, occur throughout the complex. Dark xenoliths of biotite-rich diorite and granodiorite are common.

The Urannah Complex intrudes the Connors Volcanics and is mainly overlain by the Lower Permian Lizzie Creek Volcanics and Carmila Beds; but some of the younger elements in the complex intrude the Lower Permian rocks.

## Carboniferous to Mesozoic intrusions (C-Mi)

Intrusives crop out in isolated areas in the Connors and Broadsound Ranges and east of Broad Sound in the Saint Lawrence Sheet area, and near Redbank and Armagh homesteads in the Duaringa Sheet area. Those in the ranges are similar in lithology to the Urannah Complex and are probably the result of the same igneous activity.

Table 3 - Isotopic Ages from the Duaringa and Saint Lawrence Sheet Areas

(Data supplied by A.W. Webb)

| Specimen Number | Grid Reference | Lithology | Minerals Used | Age (Years x $10^6$) | Letter Symbol on map |
|---|---|---|---|---|---|
| | Saint Lawrence Sheet | | | | |
| F55/12-1 | 209222 | Dolerite | Pyroxene | 211 | C-mI |
| -2 | 206232 | Hornblende adamellite | Hornblende | 294 $\pm$ 5** | C-Mi |
| -3 | 207233 | Hornblende adamellite | Hornblende | 302 | C-Mi |
| -4 | 197227 | Gabbro | Pyroxene | 220* | C-Mi |
| -8 | 218191 | Hornblende-biotite adamellite | Hornblende | 305 | C-Mi |
| -9 | 219191 | Biotite-hornblende granodiorite | Biotite; Hornblende | 307, 312 $\pm$ 6** | C-Mi |
| -10A | 274150 | Biotite-hornblende adamellite | Biotite; Hornblende | 230; 238 | Pui |
| -10B | 274150 | Biotite-hornblende diorite | Hornblende | 232 | Pui |
| -11 | 274166 | Hornblende gabbro | Hornblende | 245 | Pui |
| -12 | 275167 | Hornblende-biotite granodiorite | Biotite; Hornblende | 240; 239 | Pui |
| -13 | 275168 | Quartz diorite | Biotite; Hornblende | 246; 249; 247 | Pui |
| -14 | 275149 | Biotite-hornblende granodiorite | Biotite; Hornblende | 235; 235 | Pui |
| -15 | 273148 | Gabbro | Hornblende | 240 | P-Mi |
| -16 | 279169 | Hornblende gabbro | Hornblende | 247 | Pui |
| -17 | 275169 | Diorite | Biotite; Hornblende | 243; 244 | Pui |
| -18 | 275167 | Diorite | Biotite | 243 | Pui |
| -19 | 275167 | Diorite | Biotite; Hornblende | 241; 238 | Pui |
| | Duaringa Sheet | | | | |
| F55/16-2 | 268077 | Diorite | Hornblende | 236 | Pui |
| -3 | 269075 | Adamellite | Biotite; Hornblende | 237; 240 | Pui |

Note * The K content of the pyroxene is so low that there could be a $\pm$ 30% error in its determination, and consequently a similar error in the age.

** The $\pm$ denotes uncertainty additional to the normal $\pm$ 2 - 3% experimental error. It is probably due to inhomogeneity of samples.

Connors and Broadsound Ranges. The intrusions occupy topographic depressions relative to the adjacent Connors Volcanics. A mature valley surrounded by steep hills has developed on the large mass west of Tooloombah homestead; the topography is more rugged on most of the other intrusions. They are generally covered by deep soil and support thick forest cover; when cleared, they form valuable grazing land. Good outcrops are confined to creeks and to scattered rocky rises.

The intrusion near Burwood homestead consists of granite and granodiorite containing small biotite-rich xenoliths. An intrusive contact with the Connors Volcanics is exposed near the northern end of the mass. Two samples from this intrusion were determined isotopically to be about 305 million years old (Table 3).

The intrusions west of Tooloombah homestead and farther south near the Bruce Highway range in composition from granodiorite through adamellite to alkali granite. Numerous northeast-trending trachyte dykes intrude the northern part of the largest mass.

The intrusion extending east from Dacey homestead consists of adamellite and granodiorite with minor monzonite, microgranodiorite, microgranite, and granite. Hornblende is abundant in most of this mass and dykes and xenoliths are common. A dolerite dyke was dated at 211 million years and two samples of the more abundant hornblende adamellite were dated at $294 \pm 5$ and 302 million years (Table 3).

Most of the other intrusions are small and consist of only one rock type. Gabbro crops out in three small areas; two are southwest of Dacey homestead and one is southeast of the homestead. The gabbro is massive and coarse-grained and contains neither dykes nor xenoliths. The small intrusion at the head of K Creek consists mainly of medium-grained hornblende adamellite containing hornblende crystals up to half an inch long.

All intrusions intrude the Connors Volcanics. For the most part, they are older than the Lizzie Creek Volcanics and Carmila Beds, but age determinations from areas to the north indicate that they include some post-Permian elements.

Redbank homestead area. Granodiorite crops out on the south bank of the Fitzroy River, east of Redbank homestead. It consists of equal quantities of plagioclase and quartz and less abundant potash feldspar and green hornblende. The plagioclase (oligoclase-andesine) occurs as euhedral laths up to 3 mm long and is partly altered to sericite. Perthitic potash feldspar appears to be replacing plagioclase in most specimens. The quartz occurs as intergrown groups of equant grains, about 0.8 mm in diameter, and shows well developed undulose extinction. The hornblende is partly replaced by green chlorite. Accessory minerals include epidote and opaque iron ore. No contact with other rocks was seen.

Armagh homestead area. A large adamellite stock crops out in the core of the Craigilee Anticline and intrudes the Silurian-Devonian and Carboniferous rocks near Armagh homestead in the east of the Duaringa Sheet area. The rock consists of euhedral oligoclase, extensively altered to sericite and clay; slightly altered patch perthite, in part replacing plagioclase; quartz, both interstitial and euhedral; chlorite and epidote pseudomorphous after biotite; small crystals of hornblende; and accessory magnetite and sphene.

East of Broad Sound. A few small, mainly granitic bodies intrude the Lower Palaeozoic metamorphics near the eastern margin of the Saint Lawrence Sheet area. They are mainly covered by soil and were mapped by photo-interpreting the distribution of soil derived from granite.

## Permian to Mesozoic intrusions

In the northeast of the Saint Lawrence Sheet area are four small masses of adamellite and granodiorite which intrude the Carmila Beds. Their age is unknown, but they are lithologically similar to the Lower Cretaceous intrusions in the Urannah Complex farther north.

Small gabbro masses intrude the serpentinite near Marlborough homestead and 4 miles west of Marlborough. The one near Marlborough homestead has been isotopically dated at about 240 million years (Table 3). It has been recrystallized, presumably as a result of contact metamorphism by the adjacent Upper Permian intrusion, which contains many gabbroic xenoliths. The gabbro west of Marlborough lies across the faulted northwestern margin of the serpentinite, but is not itself faulted. These gabbro masses were possibly emplaced during the Permian after the serpentinite had been faulted into approximately its present position.

Two basic igneous bodies intrude the Rookwood Volcanics 8 miles south-southeast of Rookwood homestead and the Rannes Beds 2.5 miles northwest of Rookwood homestead. They are medium-grained gabbro consisting of pyroxene and plagioclase (labradorite zoned to oligoclase), interstitial chlorite and prehnite, and accessory calcite, apatite, epidote, and ilmenite. These rocks may be genetically related to the magma which produced the pillow lavas of the Rookwood Volcanics. A similar gabbro crops out between Rookwood and Foleyvale homesteads; it is probably a sill intruding the Rannes Beds. The elongate intrusion north of Leura homestead is a fine to medium-grained diorite intruding the Back Creek Group and the Carmila Beds. Small, mainly granitic bodies intrude the Lower Palaeozoic metamorphics northeast of Marlborough.

## Upper Permian Intrusions

Upper Permian intrusives were mapped around and north of Marlborough in the Saint Lawrence Sheet area and at Rookwood homestead in the Duaringa Sheet area. The intrusive at Marlborough is generally deeply weathered and occupies mainly low soil-covered areas. The largest fresh outcrop, in Marlborough Creek, 1/2 mile south of the Bruce Highway, is a hornblende-biotite adamellite containing many rounded xenoliths of partly digested basic material. The intrusion was mapped partly by air-photo interpretation and partly by examination of weathered outcrops which indicate that it is dominantly a biotite-rich adamellite or granodiorite. It intrudes the serpentinite and the metamorphics south and east of Marlborough. Age determinations (F55/12/10A, 10B, 14, Table 5) indicate an age of about 235 million years.

Eight miles north of Marlborough, a small intrusive complex of diorite, microdiorite, gabbro, and granite intrudes the Carmila Beds. The diorite is dominant in a semicircular line of hills which is thought to be the margin of a large body partly concealed by Quaternary alluvium. Other rock types in this line of hills include quartz diorite and hornblende gabbro. Granite crops out in a small area beside the road from Glenprairie homestead to Marlborough at the southern margin of the diorite. South of the granite is an area occupied mainly by gabbro and microdiorite; the microdiorite is intensely sheared near the southern margin. Ages were determined on samples of many rock types from this complex (F55/12-1, 16, 17 from the diorite mass; F55/12-12 from the granitic mass; F55/12-11 from the gabbroic mass; and F55/12-18, 19 from the margin of the granitic and gabbroic bodies). They suggest that intermediate to basic rocks were emplaced first (about 248 million years), and more acid rocks later (about 240 million years).

Adamellite intrudes the Rookwood Volcanics near Rookwood homestead. It contains euhedral laths of plagioclase zoned from oligoclase to andesine, anhedral potash feldspar (possibly microcline), poikilitically enclosing other constituents, strained interstitial quartz, large ragged flakes of biotite, scattered crystals and clots of hornblende, and accessory magnetite. This intrusion includes some diorite consisting of andesine, hornblende, and accessory apatite, sphene, and epidote. Age determinations (F55/16-2, 3) date the intrusion at about 240 million years.

### Lower Cretaceous Bundarra Granodiorite

The Lower Cretaceous Bundarra Granodiorite intrudes the Permian sequence in the northwest of the Saint Lawrence Sheet area. It occupies a depression, is poorly exposed, and is surrounded by a metamorphic aureole represented by a ring of high, rugged hills. The granodiorite is mainly leucocratic and ranges to alkali granite. Biotite is the main ferromagnesian mineral; hornblende is abundant in places and the rock approaches syenite. The Bundarra Granodiorite intruded and domed the Back Creek Group, probably during the folding of the Bowen Basin sequence. It is considered to be Lower Cretaceous by analogy with a lithologically similar syenite stock, cropping out 10 miles to the west in the Clermont Sheet area, which gave a K/Ar age of 125 million years (A.W. Webb, pers. comm).

### Cretaceous or Tertiary intrusions

A Cretaceous or Tertiary intrusion crops out at Middlemount south of Warwick homestead in the southwest of the Saint Lawrence Sheet area as a high crescentic ridge 2 miles long, surrounded by soil-covered plains. The intrusive is a light cream medium-grained trachysyenite. It is elongated parallel to the northwesterly strike of folded Permian sediments and is perhaps a sill concordant with the bedding of the sediments. Trachytic dykes and sills intrude the Back Creek and Blackwater Groups northeast of Middlemount.

A small plug intrudes the Carmila Beds at Fort Arthur in the north of the Saint Lawrence Sheet area. It is mapped as Cretaceous or Tertiary because of its geomorphic similarity to other plugs of this age in adjacent Sheet areas.

## STRUCTURAL GEOLOGY

The Duaringa and Saint Lawrence Sheet areas are mainly occupied by part of the structurally complex Bowen Basin. The Styx Basin in the east of the Saint Lawrence Sheet area, and the Duaringa Basin trending north-northwest across the centre of the area, were superimposed on the Bowen Basin, which is bounded to the east by the Marlborough Block consisting of Lower Palaeozoic(?) metamorphics and younger intrusives and by Silurian to Carboniferous rocks of the Craigilee area. The islands and peninsula east of Broad Sound consist of Devonian to Permian sediments, Lower Palaeozoic(?) metamorphics, and younger intrusives. Inliers of pre-Permian rocks occupy the cores of one major and several minor structures within the Bowen Basin. The structural elements within the area are shown on Figure 19. Boundaries between structural elements are approximate as the changes in structural style are gradational from one area to another.

The Duaringa Basin is an elongate trough between the Folded Zone to the west and the Connors Arch and the Gogango Overfolded Zone to the east. Seismic surveys across the basin (Robertson, 1961) indicate that it contains about 3500 feet of sediments overlying folded Permian rocks. The western margin of the basin is faulted. The youngest, and perhaps all, of the sediments in the basin are of Tertiary age: the base may be Cretaceous. The basin lies along a line of moderate gravity minima (Darby, 1966). The gravity data suggest that the basin is deepest, and swings northwest, in the Saint Lawrence Sheet area. There is no evidence of folding of the sediments in the Duaringa Basin.

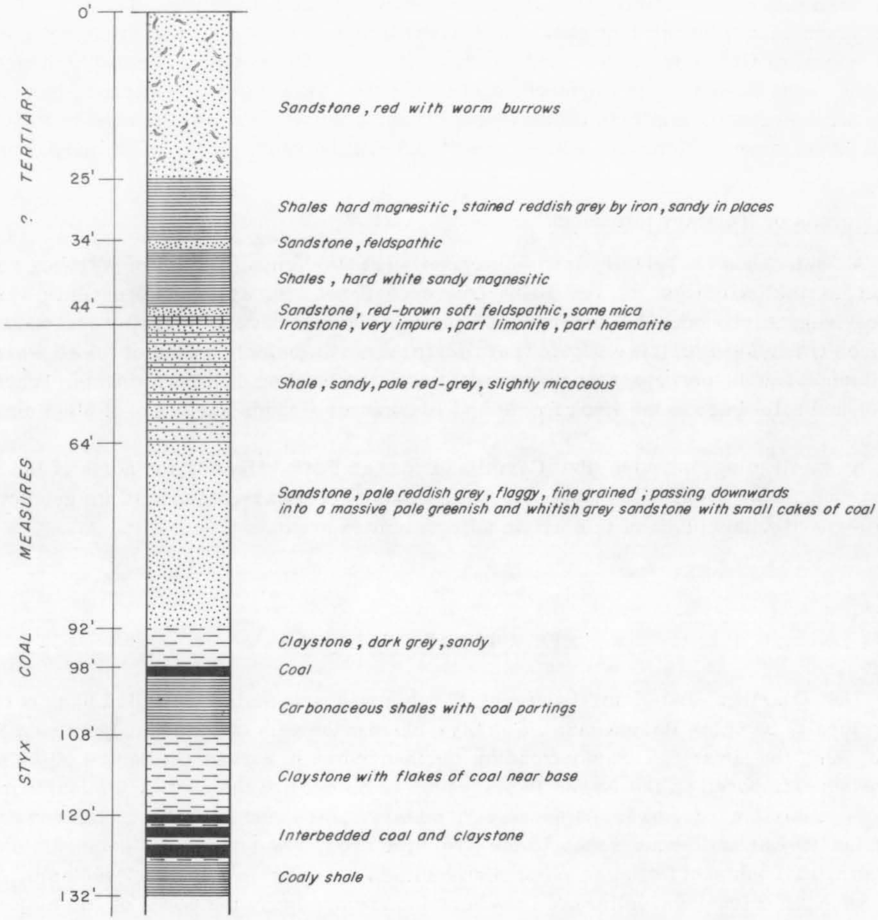



Figure 18 Measured section, Styx Coal Measures.

The Styx Basin is an elongate basin, plunging gently to the north, superimposed on the older Strathmuir Synclinorium. The basin is occupied by 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 fault, probably a high-angle reverse fault, along which the block of tightly folded Back Creek Group to the east has been uplifted. The Cretaceous sediments are folded against this fault.

## Bowen Basin

The structural elements of the Bowen Basin have been discussed previously (Malone et al., 1963; Malone, 1964).

The Comet Ridge is a broad anticlinorium with many folds of low amplitude and sinuous axial trends. Dips are generally less than 15°, but are steeper northeast of Cooroorah homestead, near the Folded Zone. AFO Cooroorah No. 1 Well (Derrington, 1960) and AFO Comet No. 1 Well (Mines Administration Pty Ltd, 1965) encountered pre-Permian rocks in the ridge at a depth of about 3000 feet. The Permian sediments dip off the ridge to the northeast into the Folded Zone, to the southeast into the Mimosa Syncline, and southwest into the Denison Trough (Derrington, 1961). To the northwest, the ridge merges into the Collinsville Shelf (Malone, 1964) on the western flank of the Bowen Basin.

The northern end of the Mimosa Syncline extends into the Duaringa Sheet area, where it consists of two prominent subparallel synclines separated by a zone of faulting and folding. Synclines are outlined by the Clematis Sandstone and plunge to the south-southeast. In the northwest the dips are very gentle and the Clematis Sandstone crops out over a wide area. An east-northeasterly fault cuts the northern end of the syncline; displacement is small and is apparently down to the south.

The Folded Zone (Dawson Tectonic Zone of Derrington, 1961) is a north-northwest zone with a slightly irregular boundary against the Mimosa Syncline and the Comet Ridge to the west and a faulted boundary against the Duaringa Basin. Outcrop is poor in the zone and most structural data were obtained from three areas of outcrop of the Back Creek and Blackwater Groups near the centre. Back Creek Group sediments domed by the Bundarra Granodiorite crop out at the northern end of the Folded Zone. In the centre of the zone, the dips and the bedding trends reveal tight subisoclinal folding with generally parallel fold axes in the south and elongate domes and basins in the north. Very tight minor folds occur on the flanks of larger structures. The style of folding in the zone is illustrated on the geological maps and by a series of cross-sections on Figure 9. Apparently, the intensity of folding decreases from south to north and from east to west. Variations in the style of folding along the zone are indicated by comparison of the stereographic projections in Figure 21. These are equal area projections of poles to bedding attitudes measured in three areas in the Folded Zone, namely: south of the Mackenzie River, Figure 21a; the Mackenzie River section, Figure 21b; and north of the Mackenzie River, Figure 21c. Fold axes in the zone trend from 330° to 340°. The regional plunge of the fold axes appears to be statistically horizontal; measurements north of the Mackenzie River indicate that the plunges of individual fold axes range from 15° to the north to 15° to the south.

The Folded Zone appears to be structurally lower south of the Mackenzie River than north. Up to 2000 feet of Back Creek Group is exposed in the cores of anticlines in the Mackenzie River section and farther north, whereas no Back Creek Group is exposed in the southern part of the zone. Since the folding is tighter in the southern area and the amplitudes are at least comparable with those to the north, and since both areas are dissected to the same topographic level, the absence of the Back Creek Group suggests that the southern area is structurally lower. A north easterly normal fault along the line of the Mackenzie River may separate the two areas and displace the southern block downwards: a similar fault cuts the northern end of the Mimosa Syncline and possibly crossed

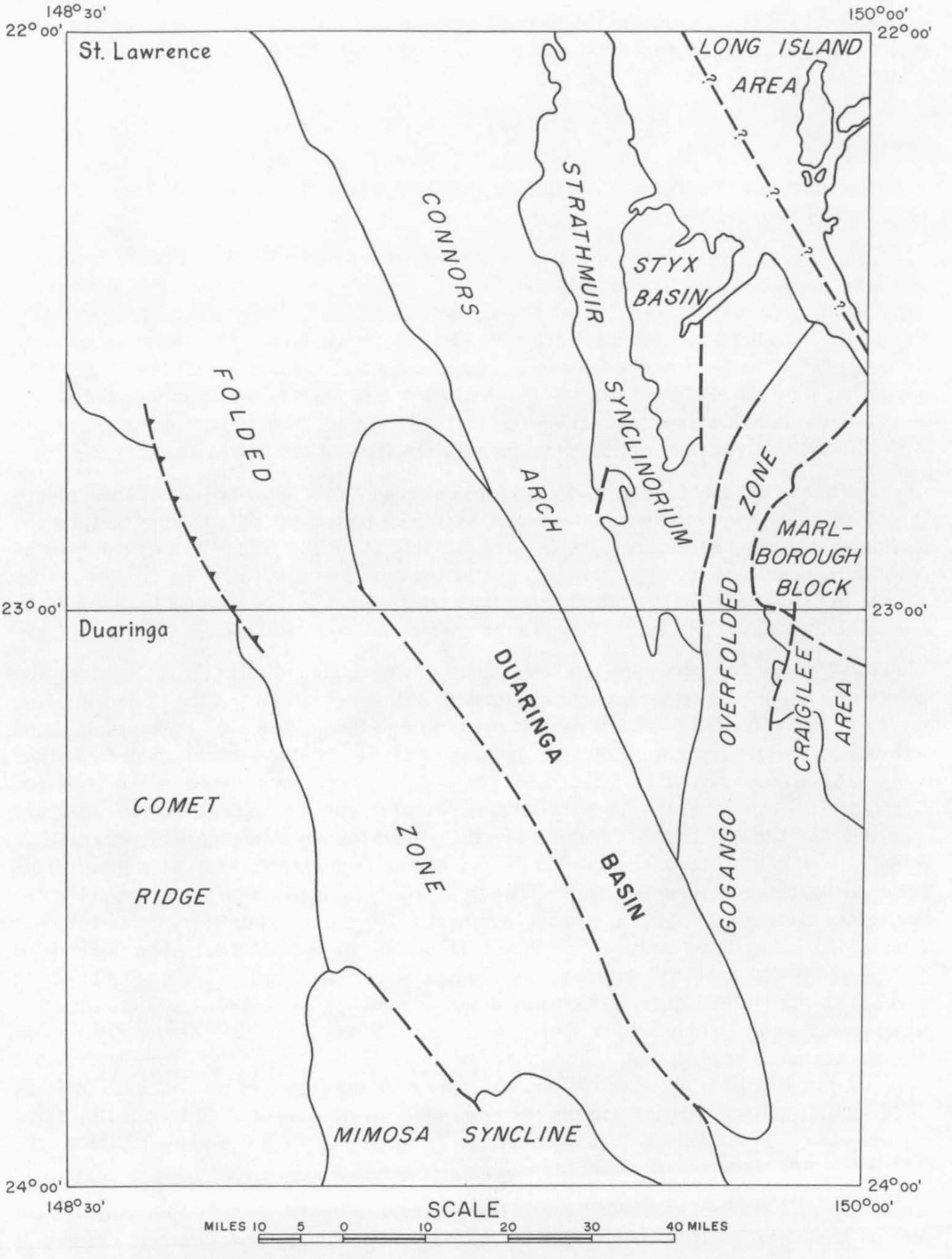
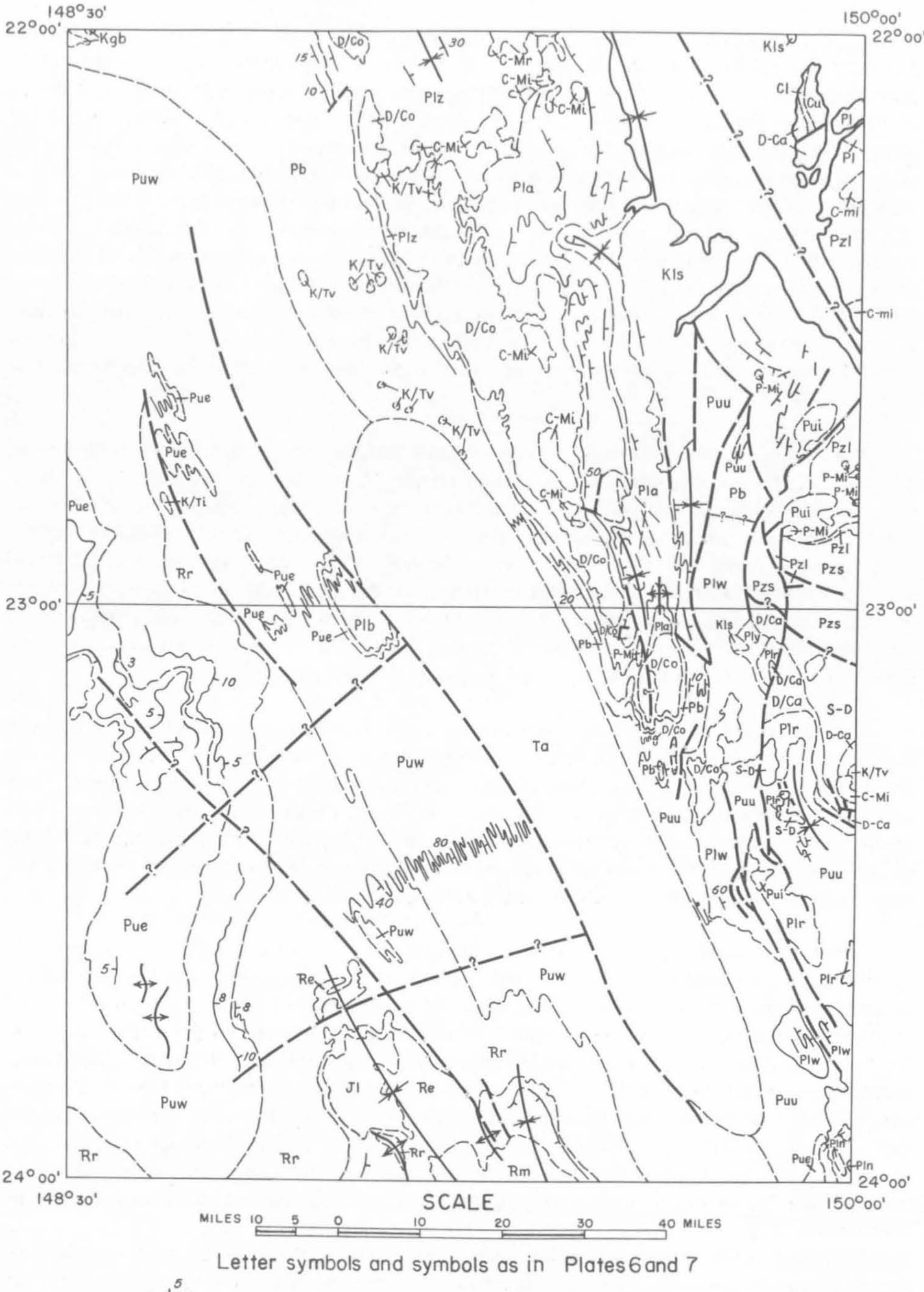



Figure 19 Structural elements, Duaringa and Saint Lawrence Sheet areas.




SCALE

MILES 10 5 0 10 20 30 40 MILES

Letter symbols and symbols as in Plates 6 and 7

*Trend lines showing direction and magnitude of dip and indicating style of folding*

Figure 20 Solid geology.

the Folded Zone. Tertiary sediments overlap the Folded Zone south of this fault line, so the zone is probably structurally lower south of the fault.

A reconnaissance seismic survey (Robertson, 1961) shows gentle dips below the Folded Zone, at a depth of about 20,000 feet; so a décollement probably separates the tightly folded Permian sediments from the underlying rocks. East-dipping axial planes and thrust faults indicate that the folding stress was from the east. Cleavage is virtually absent and jointing and faulting are uncommon. The lack of cleavage is in marked contrast to the ubiquitous cleavage of the Permian rocks east of the Duaringa Basin. The combination of a possible décollement below the zone, a thrust-faulted western margin, and the lack of cleavage suggests gravity tectonics as a possible mechanism of the folding. The Connors Arch has been very greatly uplifted since the Permian and possibly this uplift has supplied the potential energy for the gravity tectonics. In an interpretative section (Fig. 9) across the Folded Zone along a line about 25 miles north of Bundaleer homestead, a décollement is shown along the top of the Connors Volcanics, although the displacement could have been effected by bedding-plane shear at one or more horizons within the overlying sedimentary pile.

The Connors Arch forms the southern end of the Eungella Strip (Hill in Hill & Denmead, 1960, p.11). The arch appears to be a broad simple structure with the generally massive Connors Volcanics and pre-Permian intrusives exposed in the core. In the north of the Saint Lawrence Sheet area, the Lizzie Creek Volcanics and the Carmila Beds overlap the arch from the west and east and overlie the Connors Volcanics; they occupy some broad synclines which may have been depositional areas on the pre-Permian surface. Elsewhere on the Connors Arch, the Lower Permian beds are mainly gently dipping. The Carmila Beds dip off the arch to the east at $20^{\circ}$ to $40^{\circ}$; the Lizzie Creek Volcanics and the Back Creek Group dip off the arch to the west at generally less than $20^{\circ}$.

Several blocks, identified as Connors Volcanics on lithology, crop out at the southern end of the Connors Arch. These blocks are separated from the main pre-Permian core of the Connors arch and bear a very complex relationship to the overlying Carmila Beds and Back Creek Group. This is in contrast to the simple relationship which the main core of the Arch bears to the overlying Permian rocks. Apparently, these separate blocks of Connors Volcanics were local high areas during deposition of the Permian sequence, and were possibly independently mobile during subsequent deformation.

The block south of Tooloombah homestead was mapped in considerable detail to establish its relationships. The western margin of the Tooloombah block is apparently faulted against Carmila Beds dipping east off the main core of the Connors Arch. The sequence of Carmila Beds west of the Tooloombah block extends to the south and north. To the south, the Carmila Beds are overlain, with structural conformity, by a tuffaceous coquinitic marker bed which is locally the basal bed of the Back Creek Group. This bed can be traced around the northern nose of the Apis Creek Syncline and along strike to the east, where it directly overlies the Connors Volcanics of the Tooloombah block. The coquinitic bed lenses out along strike, but the remainder of the Back Creek Group sequence overlies the Tooloombah block along its southern and eastern margins. Near the north-east corner of the block is an embayment containing some Carmila Beds above the Connors Volcanics and below the Back Creek Group. Farther north, the Back Creek Group is conformable on the Carmila Beds and the two units form a sequence dipping east from the Connors Arch into the Strathmuir Synclinorium. These relationships indicate that the Tooloombah block of Connors Volcanics was a land area at times during Lower Permian sedimentation. The Carmila Beds were deposited over most of the southern part of the Connors Arch and had their main development in a trough east of the Connors Arch. Within that trough, the Carmila Beds wedged out against the high area formed by the

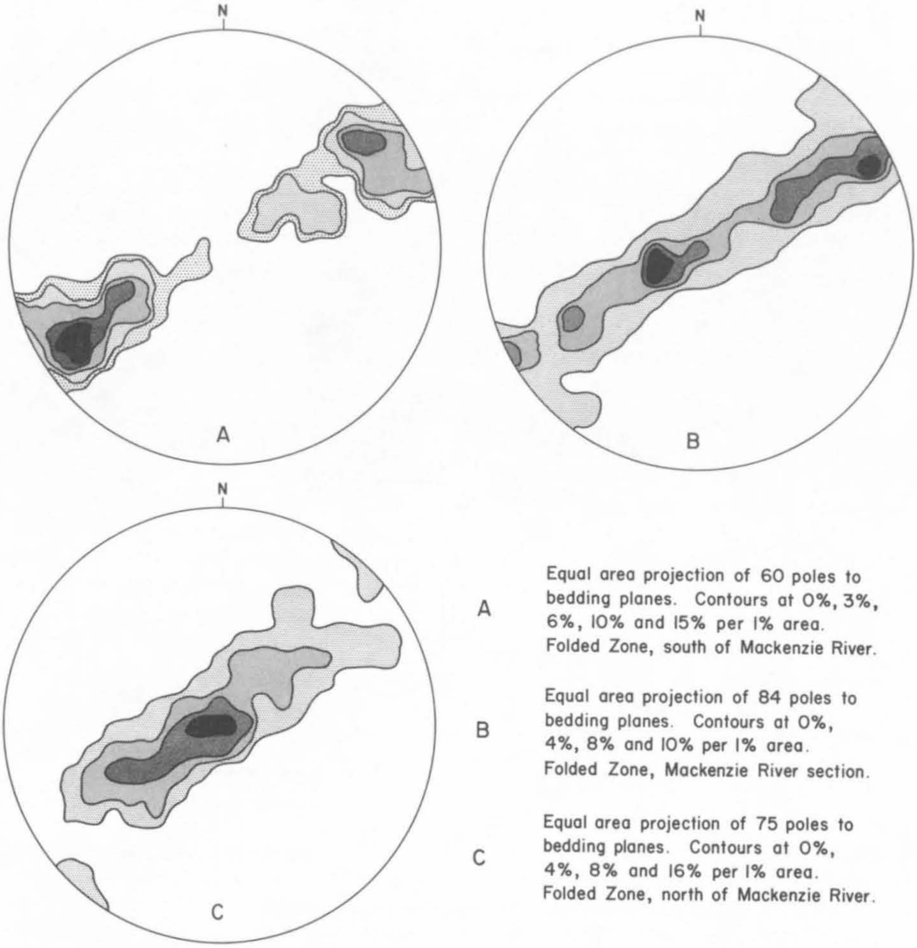



Figure 21 Contoured equal area projections of bedding-plane poles, Folded Zone.

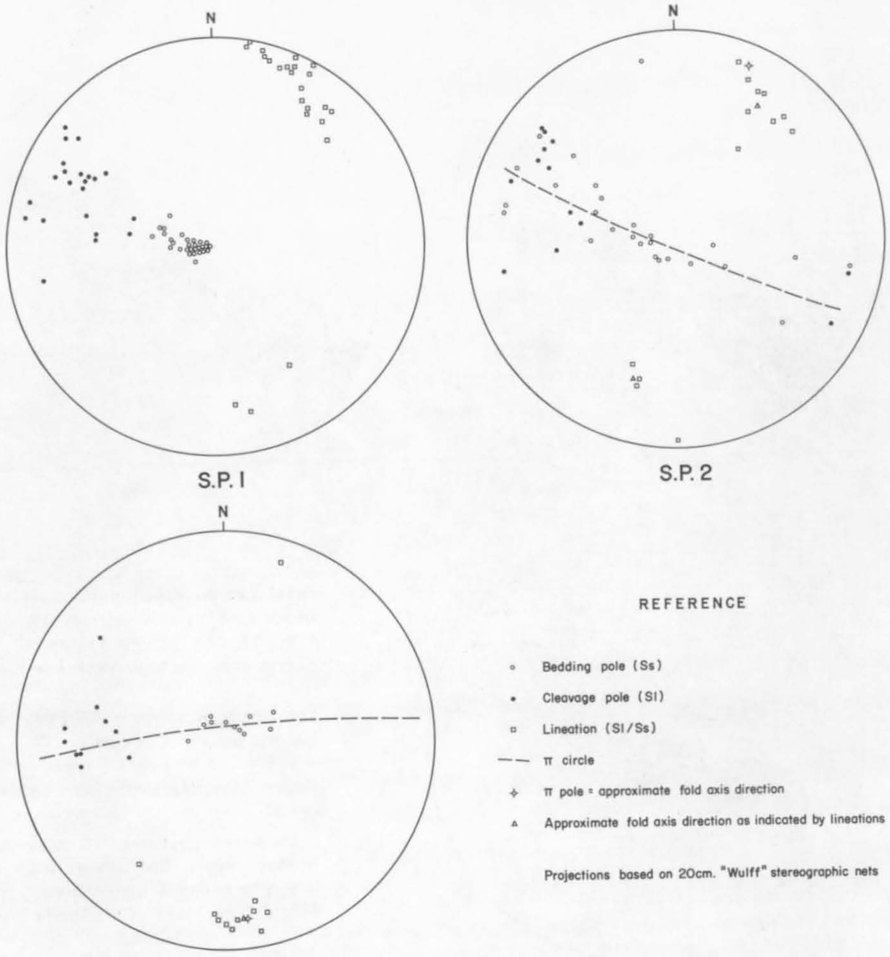



Figure 22 Stereographic projections of bedding-plane and cleavage poles and lineation directions, Leura homestead area.

Tooloombah block of Connors Volcanics and were overlapped by the basal beds of the Back Creek Group. During post-Permian deformation, the Tooloombah block was uplifted and faulted against east-dipping Carmila Beds.

The other isolated blocks of Connors Volcanics at the southern end of the Connors Arch probably bear similar relationships to the Lower Permian sequence. Certainly, the Back Creek Group overlaps the Carmila Beds around the northern end of the block of Connors Volcanics east of Leura homestead. This block has greatly influenced the deformation of the overlying sediments. Approximately 2000 feet of section, adjacent to the volcanics, dips consistently to the east at generally low angles; above this, the complexity of folding of the sequence increases rapidly. The degree of structural complexity appears to be directly proportional to distance from the underlying Connors Volcanics. Two of the stereographic projections shown on Figure 22 refer to this area, 'a' to the basal 2000 feet of section and 'b' to the overlying folded sequence. Both projections are in good agreement. The relationship and grouping of the bedding and cleavage poles indicate that the cleavage is axial-plane cleavage probably developed during one period of folding. The lineation directions are reasonably well grouped, indicating the orientation of the axis of folding. The grouping of the cleavage poles indicates that the folds are slightly overturned and their axial planes dip steeply east. Farther west, in the elongate embayment in this block of Connors Volcanics, the Back Creek Group sediments are tightly and complexly folded, cleaved and, in places, sheared. The western margin of this embayment is shown as a possible fault on Figure 20. The intense folding of the Back Creek Group in the embayment is attributed to squeezing between blocks of Connors Volcanics. Farther west, the Back Creek Group is tightly folded and cleaved adjacent to the western margin of this block of Connors Volcanics, but the intensity of folding decreases rapidly to the west. Projection 'c' on Figure 22, based on a few measurements made west of Leura homestead, indicates a change in the style of folding and in the orientation of the fold axes. The sediments are folded into broad anticlines and synclines, but are abundantly cleaved, particularly the finer-grained sediments. The cleavage dips steeply to the east, as it does farther to the east.

At the southern end of the Connors Arch, sediments mainly of the Boomer Formation are folded into a series of domes and basins elongated north-south. In this area, the regional plunge is effectively flat, dips are generally less than $50^{\circ}$, and no overturning was seen. Cleavage is abundant.

The western flank of the Connors Arch consists mainly of poorly exposed Carmila Beds or Lizzie Creek Volcanics overlain by Back Creek Group dipping gently to the west-southwest. The regional dip is interrupted by a few anticlinal noses plunging due south. The Back Creek Group is well exposed about 3 miles north of Tartarus homestead, where three sections were measured. The rock types are similar to those cropping out west of Leura homestead and the dip values are similar in the two areas, but the sediments north of Tartarus homestead are uncleaved. The cleavage in the sediments to the south is thought to be axial-plane cleavage produced by a compressive folding stress acting from the east. The absence of cleavage in the sediments on the western flank of the Connors Arch is possibly due to the protection afforded by the massive pre-Permian core of the Connors Arch.

The Strathmuir Synclinorium is an elongate structure trending north to north-northwest, occupied by Carmila Beds and Back Creek Group. At the northern end, a block of Carmila Beds dips to the east to form the western flank of a large syncline. The nose of this syncline was mapped on the Mackay Sheet area to the north, where the eastern flank of the syncline has been displaced by an upfaulted block of Devonian-Carboniferous Campwyn Beds (Jensen, Gregory, & Forbes, 1966). This fault possibly extends across Broad Sound, as shown on Figure 19. Near Saint Lawrence the structure becomes more complicated. The Carmila Beds are folded into a number of minor structures and Back Creek Group sediments are preserved in a broad east-west syncline. This minor axis and the main axis of the Strathmuir Synclinorium plunge under the Styx Basin. The western flank of the synclinorium from Saint Lawrence to Tooloombah homestead dips mainly east, though there is some local tight folding. South of Tooloombah homestead, this flank is interrupted by the block of Connors Volcanics discussed above. To the south is the Apis Creek Syncline. The central part of the synclinorium is moderately tightly folded and faulted; the intensity of deformation increases eastwards and tight folding, overfolding, and shearing are present in the Gogango Overfolded Zone. The eastern flank of the Strathmuir Synclinorium is represented only by a block of Carmila Beds cropping out west of Herbert Creek. These beds dip southeast to south into the synclinorium. At the boundary with the Gogango Overfolded Zone, the strike swings to nearly north and most dips are to the east.

The Gogango Overfolded Zone is a long arcuate zone occupied mainly by Permian sediments and volcanics, with some inliers of pre-Permian volcanics. The zone is characterized by overfolding with easterly dipping axial planes, faulting and possibly thrust faulting, and widespread development of cleavage in the finer-grained sediments. The complex stratigraphic relationships of the units and the similarity of rock types in different units make it difficult to interpret structure. In general, the pre-Permian inliers and the 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 most intensely folded formation is the youngest in the zone, the Boomer Formation, particularly where it consists of thinly interbedded siltstone and sandstone. Possibly the good bedding associated with marked changes in the competence of the beds enabled the unit to deform by flexural slip folding. The style of folding varies with the thickness and competence of the sandstone interbeds. Plate 3, figure 2 illustrates the style of folding where the sandstone beds are up to 12 inches thick and make up more than half the section. Tight, complex folding with many recumbent structures is developed where the formation consists of thinly interbedded mudstone and fine-grained sandstone, as near Thuriba homestead. Cleavage is well developed in the Boomer Formation, but there is no evidence of any shear folding involving movement along cleavage planes. The Rannes Beds are a fairly massive fine-grained sequence and have deformed mainly by movement along shear and cleavage planes. In most areas, only easterly dips could be measured, many of them probably on overturned beds; few fold noses were seen. Recumbent folding is developed in places (Pl. 1).

A complex syncline is present in the east of the zone, west of the Craigilee area. The syncline is outlined by comparatively unfolded Rookwood Volcanics, and the trough is occupied by tightly folded Boomer Formation. North of Tynan homestead, inliers of Silurian-Devonian volcanics are involved with Rookwood Volcanics and Boomer Formation in structures which are not fully understood. Apparently the Boomer Formation overlapped the Rookwood Volcanics and directly overlies 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 underneath the Rookwood Volcanics and in another place, a few miles to the south, is conformable on them.

The Craigilee area consists of the Craigilee Anticline and a westerly extension of Devonian-Carboniferous outcrop. The Craigilee Anticline is outlined by Carboniferous sediments which unconformably overlie Silurian-Devonian rocks in the core. The Silurian-Devonian rocks are mainly massive volcanics, but include some sediments, which are steeply dipping and in places tightly folded. They strike nearly at right angles to the overlying Carboniferous sediments. Dips off the anticline are about $45^{o}$ on the eastern flank and very steep to locally overturned on the western flank, where in places the Rookwood Volcanics have overlapped the Carboniferous sediments and overlie the Silurian-Devonian rocks. The Devonian-Carboniferous sediments to the northwest of the Craigilee Anticline dip at $40^{o}$ to $70^{o}$ to the east and northeast. They are overlain by the Rookwood Volcanics and are possibly faulted against the Rannes Beds.

The Marlborough Block consists of possibly Lower Palaeozoic metamorphics, and serpentinite of unknown age, intruded by Permian gabbro and granodiorite. The serpentinite is generally unsheared; but along its northwestern margin, where it is faulted against Lower Permian rocks, it is sheet-like and commonly sheared. The faulted margin dips steeply to the southeast. Few structural data were collected from the metamorphics. In most areas, they possess well developed schistosity which dips steeply and strikes east to northeast. A number of faults cut the Marlborough Block; one has displaced the laterite profile on the serpentinite and is probably of Tertiary age. The boundary between the Marlborough Block and the Craigilee area is not exposed; it may be faulted, though in the Port Clinton Sheet area to the east the serpentinite intrudes sediments which are probably equivalent to the Silurian-Devonian rocks.

The age of emplacement of the serpentinite is not known. It was probably emplaced in approximately its present position in the Lower Permian, and the emplacement probably took place in the solid state mainly by means of block faulting and thrusting.

The Long Island area is occupied by moderately folded Devonian-Permian sediments, faulted against Lower Palaeozoic(?) metamorphics to the south which are intruded by a poorly exposed Carboniferous or younger granodiorite. The area was not mapped in any detail. Air-photo interpretation indicates that the sediments strike sinuously north to northeast and dip mainly east. In general, the structural and stratigraphic data indicate that the sequence is folded into a large north-trending syncline, the eastern limb of which is covered by the sea.

## GEOLOGICAL HISTORY

The oldest rocks in the area are the Lower Palaeozoic(?) metamorphics of the Marlborough block. Little is known of the history of these rocks. There is no evidence that they played any part in controlling later deposition or folding in the area until they, and the associated serpentinite mass, were block-faulted into approximately their present position, possibly in the Lower Permian.

The Silurian-Devonian rocks represent a period of extensive vulcanism and carbonate sedimentation. A fauna collected at a locality in the Duaringa Sheet area is diagnostic of Upper Silurian; faunas collected from similar rocks in the Rockhampton Sheet area indicate Lower Devonian. Sedimentation probably continued from the Upper Silurian to the Lower Devonian. An angular unconformity separates the Silurian-Devonian rocks from the overlying Devonian to Carboniferous Yarrol Basin sequence. During the period represented by this unconformity, considerable folding took place, probably during the Middle Devonian. Locally derived conglomerates at the base of overlying units and onlapping of Carboniferous and Lower Permian units on to the Silurian-Devonian block indicate that it was a land area at times during the Yarrol Basin and Bowen Basin sedimentation.

The available palaeontological data suggest that Yarrol Basin sedimentation commenced in this area in the Upper Devonian and consequently that there was a considerable time break between deposition of the Silurian-Devonian rocks and the Yarrol Basin sequence. Farther east, deposition continued during some at least of this time and is represented by lower(?) Middle Devonian at Hunter Island (Roberts, see App. 5) and by Givetian and Frasnian volcanics near Mount Morgan.

The Connors Volcanics are inliers unconformably overlain by Lower Permian rocks. They are Lower Carboniferous or older because they are intruded by igneous bodies whose isotopic ages are about 300 million years. They cannot be correlated reliably with any other units in the area. Farther north, in the Mackay Sheet area, they were regarded as mainly terrestrial volcanic equivalents of the Devonian-Carboniferous Campwyn Beds because of similarities of lithology and stratigraphic and structural position. In the Duaringa and Saint Lawrence Sheet areas much the same similarities exist between the Connors Volcanics and some of the Silurian-Devonian volcanics and consequently deductions based on such similarities are unreliable.

In this area, the Yarrol Basin sequence consists of sediments derived from volcanics, siliceous siltstone, oolitic limestone, conglomerate, sandstone, siltstone, and mudstone. The rock types, the sequence of units, and the faunas they contain are similar in the widely spaced outcrops in the area. This suggests deposition in a very extensive uniform marine environment mainly east of the Duaringa and Saint Lawrence Sheet areas. The sequence is interrupted by several hiatuses and is unconformably overlain and overlapped by the Youlambie Conglomerate and the Rookwood Volcanics.

Deposition in the Bowen Basin began in the southeast of the Duaringa and Saint Lawrence area, where the Camboon Andesite(?) and the Rannes Beds were deposited. Both these units may consist largely of pre-Permian rocks. The Rannes Beds were deposited in a long narrow zone, now contained in the Gogango Overfolded Zone; at the southern end, they overlie the Camboon Andesite(?); at the northern end their relationships with the Carmila Beds are obscure. The Rannes Beds in the north may include equivalents of the basal Back Creek Group; both these units overlie inliers of Connors Volcanics east of Leura homestead, and are unconformably overlain by the Boomer Formation.

During the Lower Permian, the volcanics and sediments of the Lizzie Creek Volcanics and the Carmila Beds accumulated over most of the northeast of the area. They were succeeded by the marine fossiliferous Back Creek Group, though vulcanism continued in a few places. The environment became marine towards the end of deposition of the Lizzie Creek Volcanics and Carmila Beds when the sea transgressed over most of the Saint Lawrence Sheet area and the western part of the Duaringa Sheet area, while a number of islands and possibly a large emergent area occupied most of the east and southeast of the Duaringa Sheet area. In the rest of the area, marine deposition continued during the remainder of Lower Permian into the Upper Permian. In the west, the sections drilled in the Comet and Cooroorah wells indicate that a nearly complete Back Creek Group was deposited on a shallow basement of Devonian-Carboniferous rocks. The marine shale of the Tiverton Subgroup was overlain by the Gebbie Subgroup consisting of a thick, partly fluviatile sandstone at the base, a shale unit reflecting a temporary transgression, and an upper fluviatile or paralic sandstone. At the top of the sequence is the Blenheim Subgroup, consisting of a mudstone unit deposited during widespread marine transgression, overlain by partly marine, partly brackish-water coal measures.

The Youlambie Conglomerate, which is restricted to the eastern edge of the Duaringa Sheet area, was deposited in a marine environment, early in the Lower Permian. It unconformably overlies every formation from the Silurian-Devonian to the Rannes Beds; so the area was uplifted and eroded before the Youlambie Conglomerate was laid down. The Rookwood Volcanics were deposited in a marine environment over most of the eastern part of the Duaringa Sheet area; they overlie the Youlambie Conglomerate with an unconformity of unknown magnitude. They appear to be erratically distributed, suggesting extrusion from a number of submarine vents, probably fractures.

Extrusion of the spilitic pillow lavas of the Rookwood Volcanics may have been contemporaneous with emplacement of the serpentinite mass of the Marlborough Block. The serpentinite is certainly faulted against Lower Permian Carmila Beds and the ages and relationships of igneous rocks in the area suggest that the faulting possibly took place in the late Lower Permian. The serpentinite may have been emplaced, largely by means of faulting, at this time.

Sedimentation extended over the barrier of Rannes Beds and Connors Volcanics into the east of the Duaringa Sheet area in the early Upper Permian with deposition of the Oxtrack Formation in the south and the Boomer Formation elsewhere. The Boomer Formation is unconformable on the Rannes Beds, the Connors Volcanics, and the basal part of the Back Creek Group. In places it appears to be conformable on the Rookwood Volcanics; elsewhere it is unconformable on, or at least overlaps, them. To the east, it interfingers with the Dinner Creek Beds, an Upper Permian conglomerate containing clasts of fossiliferous Lower Carboniferous limestone. The grainsize of the Boomer Formation and the Dinner Creek Beds increases to the east, and apparently the Upper Permian sea was bounded to the east as well as to the northwest of the Duaringa Sheet area.

The Oxtrack Formation was deposited directly on the Camboon Andesite in the southeast of the Duaringa Sheet area and was overlain by the southern extension of the Boomer Formation. The Oxtrack Formation consists mainly of neritic limestone and coquinite and was deposited in a shallow sea advancing to the northeast across the area which had been land during the late Lower Permian.

The Boomer Formation represents the last Permian sedimentation east of the Dawson-Mackenzie Rivers line. This area was possibly uplifted about the middle of the Upper Permian, when a number of mainly acid intrusions were emplaced. About this time, the sea withdrew from the area west of the Dawson-Mackenzie Rivers line and the Blackwater Group was deposited there in a freshwater environment. Deposition was thickest in the area now occupied by the Folded Zone; a thinner but apparently complete Blackwater Group was deposited on the Comet Ridge. The depositional area probably contracted in the Triassic, and the Rewan Formation and the Clematis Sandstone were deposited mainly along the axis of the Mimosa Syncline, the Rewan in a fluviolacustrine environment and the Clematis in a fluviatile environment. These units were the last to be deposited in the Bowen Basin in this area.

The outcrops of Lower Jurassic Precipice Sandstone on the Blackdown Tableland form an outlier of the blanket sandstone at the base of the Great Artesian Basin sequence. This unit was deposited in a fluviatile environment after moderate folding and considerable uplift and erosion of the Bowen Basin sequence. The Lower Cretaceous Styx Coal Measures are preserved in a small fault-bounded area near Saint Lawrence, but two outliers of the Coal Measures suggest deposition over a much greater area. The faulting of the eastern margin of the Styx Basin took place after the Lower Cretaceous and possibly at the same time as the deformation of the Folded Zone and further shearing, faulting, and overfolding in the Gogango Overfolded Zone. The deformation in the overfolded zone possibly began during the Lower Permian uplift, continued during the period of uplift and intrusion in the Upper Permian, and was renewed after the Lower Cretaceous.

The Cretaceous-Tertiary volcanics and intrusives were possibly intruded and extruded about the end of the Cretaceous. Many of these rock types are similar to a trachyte stock at Mount Ramsay in the Baralaba Sheet area which gave an isotopic age of about 70 million years (late Cretaceous) (A.W. Webb, pers. comm.).

Tertiary sediments were spread widely, mainly as a thin sheet of fluviatile and locally lacustrine sediments. Their maximum development is in the Duaringa Basin, the western margin of which subsided, probably accompanied by normal faulting, east block down, after the compressive folding of the Folded Zone. Basalt sheets are interbedded with the Tertiary sediments in places and probably dammed the drainage, producing lakes in which the sediments were deposited. Elsewhere, the basalt overlies the sediments. Extensive lateritization took place in the Tertiary and particularly thick laterite profiles developed on the flat-lying, little consolidated Tertiary sediments. The laterite profiles have helped to preserve the Tertiary sediments from erosion. Displacement of the laterite profile on the serpentinite mass indicates late Tertiary faulting in this area. Extensive fluviatile sediments were deposited in the flood plains of the Isaac, Dawson, and Mackenzie Rivers, and piedmont deposits have accumulated on the slopes of the Blackdown Tableland and the ranges since the end of the main period of lateritization. These sediments are being eroded at present and the streams are depositing another cycle of alluvium.

## ECONOMIC GEOLOGY

### Coal

Coal has been produced from two areas: the central part of the Duaringa Sheet area, from the Upper Permian Blackwater Group; and the eastern part of the Saint Lawrence Sheet area, from the Lower Cretaceous Styx Coal Measures.

Duaringa Sheet area. Coal has been found over a large area of the Duaringa Sheet, but hitherto has been mined in the Rangal and Bluff areas only. It was first recorded by Leichhardt (1847) in 1845, cropping out in the banks of the Mackenzie River. Most of the following information has been obtained from Warden's Reports for the Rockhampton and Clermont Fields, published in Annual Reports of the Queensland Department of Mines.

Several shafts were sunk, and tunnels driven, near Tolmies before 1895 to prospect two seams which crop out in the area (Maitland, 1895; Dunstan, 1910). The lower seam is 7 feet thick, but contains numerous shale bands. The coal is of poor quality.

For several years after 1900 a seam up to 24 feet thick (the Mammoth seam) was prospected near Jellinbah homestead, and traced south towards the Central Railway. The Mammoth Coal Company sank a shaft near Jellinbah homestead, later abandoned in favour of a second shaft on Frenchmans Plains, about 7 miles north of Blackwater. Although the coal was of good quality, only small amounts were produced because cost of transport to the Central Railway made operations uneconomic. Between 1913 and 1920 the Mount Morgan Gold Mining Company Limited tested the Mammoth seam between Blackwater and Frenchmans Plains by boring. A shaft was sunk about 6 miles north of Blackwater, but was abandoned because of high transport costs. The Mount Morgan Company eventually obtained coal from Baralaba when Baralaba and Mount Morgan were connected by rail.

Several companies prospected the area between Duaringa and Triphinia from 1900 to 1911, and several steeply dipping anthracitic coal seams up to 10 feet thick were located. The coal was not exploited, mainly because of lack of markets. Coal was discovered cropping out in Duckworth Creek, near Bluff, in 1903, and the first colliery in the area began operating in 1905. Four collieries have operated in the Bluff area, but have since closed. The various collieries, their period of operation, and approximate production figures to 1960 are:

| | |
|---|---|
| Bluff Colliery (1905-1925) | 165,000 tons. |
| Windsor Colliery (1933-1957) | 250,000 tons. |
| Excel Colliery (1939-1960) | 345,000 tons. |
| Cambria Colliery (1926-1960) | 550,000 tons. |

The total production from the field is about 1,310,000 tons.

The Cambria mine worked a 12-foot seam, and the Excel and Cambria a 6-foot seam. The two seams are separated by about 140 feet of shale, siltstone, and sandstone. The coal varies from low volatile bituminous coal to semianthracite. Ridgeway (1940) and Reid (1944a and b, 1947) have described the mines of the Bluff area. Ridgeway calculated actual reserves of 4,000,000 tons and probable reserves of 54,000,000 tons.

A colliery at Rangal produced about 140,000 tons of coal from a 10-foot seam between 1923-1940.

Utah Development Company is currently evaluating reserves of coking coal accessible by open-cut mining, mainly in the Blackwater area, north and south of the Central Railway. The company has a contract to supply coal to Japan and is expected to start open-cut mining south of Blackwater in 1967. Other companies now evaluating reserves are: The Broken Hill Proprietary Co. Ltd, Thiess Bros Pty Ltd, Clutha Development Pty Ltd, The Bellambi Coal Company Ltd, and Associated Mining.

Saint Lawrence Sheet area

Styx Coal Field: Coal was first discovered in the Styx River area in 1887, and prospecting ensued for two or three years. It was not until 1918 that a shaft was sunk by the Queensland Government at Bowman to exploit a promising seam previously located by diamond drilling. Production began at the Styx No. 1 State Colliery, Bowman, in the following year. A second shaft (Styx No. 2 State Colliery, Bowman) was sunk 10 chains to the south. The mines at Bowman were abandoned in 1925 in favour of a third pit begun in 1923 at Ogmore, 2 1/2 miles to the north. This mine worked for two years as Hartley State Colliery, and then continued until 1963, on the one seam, as Styx No. 3 State Colliery, Ogmore. Private enterprise entered the field in 1930, when the Bowman Coal Mining Syndicate opened up a colliery adjacent to the old State Mines at Bowman. Production from the Styx Coal field is tabulated below:

| Colliery | | Production (Tons) | Value (£) | Years of Production |
|---|---|---|---|---|
| Styx No. 1, Bowman | | 4 930 | 4 800 | 1919-21 |
| Styx No. 2, Bowman | | 103,344 | 106,261 | 1921-25 |
| B.C.M.S., Bowman | | 62,193 | 61,032 | 1932-48 |
| Styx No. 3, Ogmore | | 1,556,251 | 2,831,318 | 1924-61 |
| | TOTAL | 1,726,718 | 3,003,411 | 1919-61 |

From 1948 to 1951, the Queensland Mines Department tested an area near Tooloombah Creek, by diamond drilling (Geol. Surv. Qld, 1955). Several seams, of which three were more than 3 feet thick, were found. The drilling proved reserves of 4 million tons of coal in seams more than 3 feet thick, half of which was in seams over 4 feet thick. These reserves have not yet been exploited.

Saint Lawrence Township area: The ocurrence of coal in the Saint Lawrence area was known before 1889. The Broadsound Coal Company engaged in a vigorous prospecting campaign between 1889 and 1891. Seven boreholes and at least five shafts were put down in the vicinity of Saint Lawrence. They were successful in locating coal in a shaft within 1/4 mile of the wharf at Newport, on Waverley Creek, about 3 1/2 miles southeast from Saint Lawrence. However, an influx of water in June 1891 forced the mine to close and no production is recorded. A coal sample from a dump near the old shaft contained: 63.6 percent fixed carbon, 24 percent volatiles, 9 percent ash, and 3.4 percent moisture.

Chromite

Small deposits of chromite have been mined at several places in the ultrabasic complex. The chromium/iron ratio is below that required for chrome ore. Some chromite has been mined for use as metallurgical ore. A chromite floater, collected during the 1962 season, contained 27.7 percent chromium and 14.4 percent iron. Small deposits of chromite may be found in the ultrabasic complex.

Chrysoprase

Chrysoprase occurs as veins in the laterite profile developed on serpentinite in the southeast of the Saint Lawrence Sheet area. It was first reported from the area by Dunstan (1913, 1921). In June 1963 a deposit of gem quality chrysoprase was discovered 10 miles south of Marlborough homestead. Several tons of chrysoprase have been taken from shallow pits since the latter half of 1963 and exported mainly to Germany and USA. The Marlborough chrysoprase deposits have been described by Brooks (1964).

The chrysoprase veins are up to 8 inches wide, but usually less than 4 inches, and have been found over a wide area. They occur in the remnants of a once widespread laterite profile developed over the serpentinite, which, in outcrop, covers an area of at least 200 square miles. The chrysoprase ranges from pale green to bright apple-green; the best quality chrysoprase is bright apple-green and flawless. It consists of microgranular quartz or a mixture of microgranular and fibrous quartz. Specimens of bright apple-green chrysoprase contain from 2-2.38 percent nickel (Brooks, 1964). Associated with the chrysoprase are chalcedony, common opal, moss agate, and magnesite.

Copper

Copper has been recorded from Connors Volcanics northeast of Balcomba homestead and in the Collaroy homestead area. The copper occurs as native copper, sulphide, oxide, and carbonate in veins which are generally irregular and discontinuous.

Gold

Gold was discovered at Yatton, 7 miles east-southeast of Croydon homestead, around 1880, and about 5000 ounces of gold was estimated to have been won by gully-raking before the field was proclaimed in 1886. Recorded production since then has been negligible, and the field was abandoned by 1891. Jack (1888) described the field, and referred to 'dioritic country rock intersected by dykes of silicated felsite'. The gold occurs as flakes associated with quartz, calcite, and siderite in brecciated zones within the diorite.

Gold also occurs in quartz veins cutting volcanics of the Carmila Beds in the Salt Hill area 9 miles north-northeast of Saint Lawrence. The only production recorded is 7 ounces of gold in 1950.

Gold was discovered in the Mount Cassidy area in the northeast of the Duaringa Sheet area in 1930 (Reid, 1931). The gold is associated with an aplite dyke in Silurian-Devonian volcanics and sediments. None was mined.

Gold diggings are present in the Rannes Beds west of Grantleigh Siding in the east of the Duaringa Sheet area. Production figures are not available for that area.

Iron

Boulders of iron ore are contained in reworked laterite near the southwest of the serpentinite. The quantity and quality of the iron ore are not known.

Limestone

Connah (1958) reported a limestone belt up to 220 feet thick near Yatton. The distance from the railway is a serious disadvantage. Other thick limestone beds occur in the Carboniferous and Silurian-Devonian sequences in the Craigilee homestead area.

Magnesite

Magnesite was noted at several places in the ultrabasic complex south and southeast of Marlborough. The magnesite is generally high-grade and occurs in veins of various sizes. The most important mine is Frasers Workings, 6 1/2 miles south-southeast of Marlborough. Reserves are probably a few thousand tons; only small amounts have been mined.

It was noted in the field that the magnesite was often close to gabbro dykes; its presence may be due to alteration of the serpentinite by the gabbro.

Molybdenite

Ball (1918a) reported quartz-molybdenite veins with some chalcopyrite cutting granite in the Connors Range, near Cardowan, 28 miles northwest of Saint Lawrence. No production is recorded, and of three samples assayed one contained 0.6 percent $MoS_2$ and the others contained less.

Nickel

Two specimens collected during the 1962 survey from the laterite profile on serpentinite southwest of Marlborough were analysed; one specimen from low in the profile contained 0.63 percent nickel and the other, from higher in the profile, contained 0.19 percent nickel. An iron ore boulder from the ferruginous zone of the laterite profile contained 0.16 percent nickel and 0.88 percent chromium. The laterite profile has been eroded from most of the ultrabasic complex. Prospecting for lateritic nickel deposits and nickel silicate concentrations is currently proceeding.

Oil Shale

Tertiary oil shale has been recorded from bores in the Duaringa area and outcrops in the Dawson River southeast of Duaringa. Distillation tests on samples from outcrop gave yields of 10-21 gallons per ton. A drilling programme carried out by the Queensland Mines Department west of Duaringa revealed only thin beds of oil shale within 200 feet of the surface.

Ball (1927) reported a shale from Styx Pit, which on destructive distillation yielded crude oil at 1 gallon per ton.

Phosphate

Nodules collected from the Rannes Beds in road cuttings 8 miles east of the Dawson River contain 27 percent $P_2O_5$. The nodules, which are up to 12 inches in diameter, occur in highly sheared argillaceous sediments.

Water

There are no artesian water bores in the area. The rainfall of the area is reasonably high and the pastoralists rely on surface water and dams for most of their water. Many bores have been sunk into river alluvia to supplement surface water supplies during the dry winter months. A few bores have been sunk in the Blackwater Group and the Back Creek Group of the Comet Ridge area; some have tapped good aquifers, but nothing is known of the distribution of the aquifers. Very few records of these bores exist.

Petroleum

The eastern region of the Duaringa and Saint Lawrence area consists mainly of volcanics and complexly folded, intruded, and metamorphosed sediments. There is virtually no possibility of petroleum production from these rocks.

Farther west, in the Folded Zone, the sediments are not metamorphosed to any extent and intrusions are rare. The Blackwater Group includes good cap rocks and the Back Creek Group includes source and possible reservoir rocks. However, the structures are very tight throughout most of the zone. The steep dips make seismic prospecting almost impossible, and it would be difficult to locate structural targets. In addition, the areal extent of closure would probably be fairly small because of the tight folding.

Nothing is known of the rock types and structure of Permian sediments between the Folded Zone and the eastern region. This is probably, though not necessarily, a zone of tight folding.

Near the western margin of the Folded Zone structures are broader and flank dips are gentler. A complex anticline, closed in Blackwater Group, was mapped in the Saint Lawrence Sheet area, 9 miles southeast of Foxleigh homestead. This structure has closure over an area possibly up to 10 square miles and probably persists at depth. The western margin of the Folded Zone and farther west, particularly in the Saint Lawrence Sheet area, may be quite prospective. Here, the Back Creek Group and the lower part of the Blackwater Group contain considerable thicknesses of quartz sandstone which are potential oil reservoirs. The area is on the western flank of the Bowen Basin, where up-dip migration of oil from potential source rocks in the deeper part of the basin is possible.

The attractiveness of this area is reduced by the results from the drilling of AFO Cooroorah No. 1 Well. The well penetrated about 3000 feet of Back Creek Group, including much quartz sandstone. However, the sandstone was hard and siliceous and had very little porosity. It is not known if silicification of the sandstone is a local phenomenon or is widespread in the area. If widespread, then the potential of this formation for hydrocarbon production is very limited.

The Back Creek Group in the Comet Ridge area is gently folded and unaltered, and includes considerable thicknesses of quartz sandstone. The sequence may contain accumulation of oil or gas. However, the structures are shallow and sinuous and some apparent culminations may not be effectively closed. Closure in the Blackwater Group is probably necessary to ensure an effective cap over any structures. The sequence was unsuccessfully tested in 1965, when AFO Comet No. 1 Well was put down 8 miles southeast of Comet.

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## APPENDIX 1

## PERMIAN MARINE MACROFOSSILS FROM THE SAINT LAWRENCE AND DUARINGA SHEET AREAS

by

J.M. Dickins

### SUMMARY

Fossils are recorded from Rannes Beds(?), Lizzie Creek Volcanics, Carmila Beds, and Back Creek Group and range in age from late Sakmarian or early Artinskian (Lower Permian) probably to Kazanian (early Upper Permian). Relatively few species are added to those recorded in previous reports by the author, and the faunal subdivisions (Faunas I, II, III, and IV) previously recognized are further examined and amplified.

The Rannes Beds(?) contain a single specimen of Eurydesma and apparently Fauna I or Fauna II is represented. The Lizzie Creek Volcanics and the Carmila Beds contain Fauna I, and some fossils which are either Fauna I or low in Fauna II - possibly only Fauna I is represented.

Most of the localities of the Back Creek Group in the eastern parts of the area contain Fauna II, which is the lowermost fauna of the Back Creek Group to the north and is found in the Tiverton Subgroup. Possible exceptions are Du 1022A from the Leura Creek area, which may contain Fauna I; Du 686 from near Tartarus homestead, which contains Fauna III or Fauna IV; and a collection in the Geological Survey of Queensland from near Kooltranda Railway Station, which may contain Fauna III. In the northern part of the basin, Fauna III is found in the Gebbie Subgroup and Fauna IV is found in the Blenheim Subgroup. The Folded Zone in the middle part of the area contains only Fauna III and Fauna IV. Molluscs of Fauna III are associated with brachiopods characteristic of the Ingelara Formation of the Springsure area: which is an indication that the Ingelara contains Fauna III. Equivalents of the clarkei bed of the Clermont Sheet area and the Streptorhynchus pelicanensis Bed of the Collinsville area are apparently present. In the western part of the Duaringa Sheet area only Fauna IV is found. The Crocker Formation appears to be close in age to the Streptorhynchus pelicanensis Bed.

Only Blenheim Subgroup with Fauna IV is represented in the Thuriba homestead area in the southeast part of the Duaringa Sheet.

TABLE 1

SPECIES DISTRIBUTION, SAINT LAWRENCE AND DUARINGA SHEET AREAS

| | Fauna I | Fauna I or II | Fauna II | Fauna III | Fauna III or IV | Fauna IV |
|---|---|---|---|---|---|---|
| Astartella? sp. | X | | | | | |
| 'Megadesmus' cf. antiquata (Sowerby, 1838) | X | | | | | |
| Oriocrassatella sp. | X | | | | | |
| Walnichollsia sp. nov. | X | | | | | |
| Neospirifer sp.? | X | | | | | |
| Strophalosia cf. jukesi Maxwell, 1954 | X | | | | | |
| Strophalosia cf. preovalis or jukesi | X | | | | | |
| Myonia cf. davidis Dun, 1932 | X | X | | | | |
| Deltopecten limaeformis (Morris, 1845) | X | X | X | | | |
| Eurydesma hobartense Johnston, 1887 | X | X | X | | | |
| Keeneia sp. | X | X | X | | | |
| Anidanthus springsurensis (Booker, 1932) | X | X | X | | | |
| Cancrinella farleyensis (Eth.& Dun, 1909) | X | X | X | | | |

| | Fauna I | Fauna I or II | Fauna II | Fauna III | Fauna III or IV | Fauna IV |
|---|---|---|---|---|---|---|
| Ingelarella ovata Campbell, 1961 | X | X | X | | | |
| Notospirifer hillae Campbell, 1961 | cf. | X | X | | | |
| Strophalosia preovalis Maxwell, 1954 | X | X | X | | | |
| Cancrinella sp. | X | X | X | | X | |
| Fenestellid Bryozoans | X | X | X | | | X |
| Ingelarella profunda Campbell, 1961 | X | | X | | | |
| Notospirifer sp.A | A | | ? | | | |
| Straight nautiloid | X | | X | ? | | |
| Lissochonetes sp. | X | | X | X | X | |
| Single corals | X | | X | X | | X |
| Crinoid stem ossicles | X | | X | | X | X |
| Astartila cf. gryphoides (de Kon., 1877) | X | | | X | | |
| Astartila? sp. | | X | | | | |
| Deltopecten cf. illawarensis (Morris, 1845) | | X | | | | |
| Deltopecten cf. squamuliferus (Morris, 1845) | | X | | | | |
| Aviculopecten tenuicollis | | X | | | | |
| Aulosteges randsi Hill, 1950 | | X | | | | |
| Notospirifer sp.nov.? | | X | | | | |
| Ingelarella plana Campbell, 1960 | | X | | | | |
| Strophalosia brittoni Maxwell, 1954 | | X | | | | |
| Taeniothaerus sp. | | X | | | | |
| Terrakea pollex Hill, 1950 | | X | | | | |
| Sponge spicules | | X | | | | |
| Peruvispira sp. | | X | | X | | |
| Neospirifer (Grantonia) cf.hobartensis (Brown, 1953) | | X | X | | | |
| Trigonotreta sp.A. | | X | X | | | |
| Favosites-like corals | | X | X | | | |
| Conulariids | | X | X | | | |
| Atomodesma (Aphanaia) sp. | | X | X | X | | X |
| Aviculopecten sp. | | X | X | | X | X |
| Cancellospirifer sp. | | X | X | | | X |
| Neospirifer sp.A. | | X | X | | | X |
| Cladochonus sp. | | X | X | | | X |
| Stenoporoids | | X | | | | X |
| Cypricardinia? sp. | | | X | | | |
| Modiolus sp. | | | X | | | |
| Streblochondria? sp. | | | X | | | |
| Streblopteria sp. | | | X | | | |
| Mourlonia (Mourlonia) sp. nov. | | | X | | | |
| Dielasmatids | | | X | | | |
| Ingelarella plana or ovata | | | | | X | |
| Pseudosyrinx sp. | | | X | | | |
| Atomodesma sp. | | | X | ? | | |
| Conocardium sp. | | | X | X | | |
| Plagiostoma? sp.nov. | | | X | | | X |
| Chaenomya sp.nov.B. | | | | X | | |
| Glyptoleda? sp. | | | | X | | |
| Glyptoleda or Phestia sp. | | | | X | | |
| Notomya or Pyramus sp. | | | | X | | |
| Nuculopsis (Nuculopsis) sp. | | | | X | | |
| Parallelodon | | | | X | | |

| | Fauna I | Fauna I or II | Fauna II | Fauna III | Fauna III or IV | Fauna IV |
|---|---|---|---|---|---|---|
| Bembexia sp. | | | | X | | |
| Platyteichum costatum? Campbell, 1953 | | | | X | | |
| Attenuatella sp.nov. | | | | X | | |
| Plekonella acuta Campbell, 1953 | | | | X | | |
| Serpulids | | | | X | | |
| Strophalosia sp.nov. | | | | X | ? | |
| Ingelarella angulata Campbell, 1959 | | | | X | X | |
| Ingelarella ingelarensis Campbell, 1960 | | | | X | cf. | cf. |
| Cancrinella magniplica Campbell, 1953 | | | | | X | |
| Astartidae gen.nov.sp? | | | | | X | |
| Glyptoleda cf. glomerata Fletcher, 1945 | | | | | X | |
| Megadesmus cf. grandis (Dana, 1847) | | | | | X | |
| Notomya sp. | | | | | X | |
| Stutchburia compressa (Morris, 1845) | | | | | X | |
| Peruvispira cf. imbricata Waterhouse, 1963 | | | | | X | |
| Mourlonia (Mourlonia) cf. strzeleckiana (Morris, 1845) | | | | | X | |
| M. (Platyteichum) cf. coniforme (Eth. jun., 1892) | | | | | X | |
| M. (Platyteichum) cf. costatum Campbell, 1953 | | | | | X | |
| Warthia sp. | | | | | X | |
| Trigonotreta? sp. | | | | | X | |
| Ingelarella cf. havilensis Campbell, 1960 | | | | | X | X |
| Notospirifer minutus Campbell, 1960 | | | | | cf. | X |
| Terrakea solida (Eth. & Dun, 1909) | | | | | cf. | X |
| Flat Dielasmatid | | | | | | X |
| Ingelarella mantuanensis Campbell, 1960 | | | | | | X |
| Ingelarella pelicanensis Campbell, 1960 | | | | | | X |
| Ingelarella cf. plana or mantuanensis | | | | | | X |
| Licharewia? sp. | | | | | | X |
| Neospirifer sp.B. | | | | | | X |
| Plekonella sp. | | | | | | X |
| Punctate or spinose spiriferoid | | | | | | X |
| Streptorhynchus pelicanensis Fletcher, 1952 | | | | | | X |
| Strophalosia cf. brittoni var. gattoni Maxwell, 1954 | | | | | | X |
| Strophalosia cf. clarkei (Eth. sen., 1872) | | | | | | X |
| Strophalosia cf. clarkei var. minima Maxwell, 1954 | | | | | | X |
| Strophalosia cf. ovalis Maxwell, 1954 | | | | | | X |
| Terebratuloid | | | | X | | X |
| Thamnopora sp. | | | | | | X |
| Crinoid cup | | | | | | X |

## INTRODUCTION

Fossils from the Emerald, Clermont, Mount Coolon, Bowen, and Mackay Sheet areas of the Bowen Basin have been considered in previous reports (Dickins, 1964a; 1964b; 1964c; 1966). This study is now continued. Pelecypods, gastropods, and brachiopods are considered at the specific level and the faunal subdivisions of previous reports have been used and amplified. Although the latest publications have been used, in the absence of detailed descriptive work on many of the species, the identifications must be regarded, at least partly, as tentative. A special effort, however, has been made, by comparing actual specimens, to ensure that the identifications are internally consistent.

I am grateful to K.S.W. Campbell of the Australian National University, J.F. Dear of the Geological Survey of Queensland, and Dorothy Hill of the University of Queensland, for discussion.

The fossils are considered in general stratigraphical order from oldest to youngest corresponding to the order used in the main Report. Grid references are given for the localities.

## THE FAUNAS AND THEIR RELATIONSHIPS

### Rannes Beds(?)

Du 188 5 miles east-northeast of Balcomba homestead. Grid ref. 255088, Duaringa Sheet.

Pelecypods

Eurydesma cf. hobartense

### Relationships

Eurydesma is not a constituent of faunas younger than Fauna II; possibly Fauna I or Fauna II is represented. The locality is in a structurally complex area where the rocks have been mapped as Rannes Beds - how useful the fauna is for indicating the age of all or part of the Rannes Beds is not clear (see main Report).

### Lizzie Creek Volcanics

Fauna I

Sl 199. 3 miles west of Collaroy homestead, about 1/4 mile west of the Connors River. Grid ref. 190251, Saint Lawrence Sheet.

Pelecypods

Astartila cf. gryphoides,[1] Myonia cf. davidis, 'Megadesmus' cf. antiquata, Eurydesma cf. hobartense, Deltopecten limaeformis, Aviculopecten sp. ind. [2], Oriocrassatella sp., and Astartella? sp.

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1 Since these lists were prepared, this group of pelecypods has been reviewed by Runnegar (1965). Reference should be made to this paper for the most up-to-date information on these species.

2 Possibly all the forms referred to Aviculopecten in this appendix belong to Etheripecten Waterhouse, 1963. However, because their relationship with Etheripecten remains to be clarified, and for consistency with other fossil reports in the Bowen Basin, Aviculopecten is retained.

Brachiopods

Cancrinella cf. farleyensis, Strophalosia preovalis (possibly S. jukesi is also present), Aulosteges? sp.ind., Liessochonetes sp., Neospirifer sp.? (seems to differ from other species in having poorly developed fasciculation), Ingelarella ovata, and Notospirifer cf. hillae (has six lateral plicae).

Straight nautiloid

Single corals

Fauna I or II

Sl 22. 2 miles southwest of Collaroy homestead.
Grid ref. 192247, Saint Lawrence Sheet.

Pelecypods

Eurydesma hobartense, Deltopecten limaeformis, and Deltopecten cf. illawarensis (one fragmentary specimen with broad primary ribs).

Brachiopods

Cancrinella farleyensis, Strophalosia preovalis, Aulosteges? sp. ind., Neospirifer (Grantonia) cf. hobartensis, and Notospirifer sp.? (possibly N. sp. nov. from Fauna I).

Bryozoans

Fenestellids and stenoporoids.

SL 59. Small conical hill, 1 mile east of Marylands homestead.
Grid ref. 199239, Saint Lawrence Sheet.

Pelecypods

Myonia cf. davidis, Deltopecten limaeformis, and Stutchburia sp. ind.

Gastropods

Keeneia sp. and Peruvispira sp. (as at Sl 608, may be comparable with P. elegans (Fletcher, 1958)).

Brachiopods

Cancrinella sp., Anidanthus springsurensis, Strophalosia preovalis, Strophalosia brittoni, Aulosteges cf. randsi, Taeniothaerus sp., Neospirifer (Grantonia) cf. hobartensis, Neospirifer sp. A.*, and Notospirifer hillae.

SL 60. 2 1/2 miles north of Marylands homestead, on western side of Collaroy Creek. Grid ref. 195242, Saint Lawrence Sheet.

Brachiopods

Anidanthus springsurensis, Strophalosia preovalis, Neospirifer (Grantonia) cf. hobartensis, Ingelarella plana, and Notospirifer hillae Campbell, 1961.

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* Two species are now recognized within the grouping Neospirifer sp. previously used (see Dickins, in press a). Neospirifer sp. A can be distinguished from Neospirifer (Grantonia) cf. hobartensis by having the sulcus and the main plicae (fasciculae) less well developed. Neospirifer sp. B, which has been found only in Fauna IV, has an even less well developed sulcus and the flanks are relatively smoother. Neospirifer sp. A appears to range from Fauna II, and possibly Fauna I, into Fauna IV.

## Relationships

Of the four localities from which fossils have been collected in this area, SL22 and especially SL 199 are low in the sequence. SL 199 is assigned to Fauna I largely on the occurrence of 'Megadesmus' cf. antiquata and because of its low position in the sequence. 'M'. antiquata is found in the Allandale Formation of the Hunter Valley of New South Wales. Forms related to D. illawarensis and N. sp. nov. suggest that SL22 may represent Fauna I rather than Fauna II. The evidence, however, is not clear cut. Keeneia sp. and Aulosteges cf. randsi suggest that SL 59 is in Fauna I or low in Fauna II, similar in stratigraphical position to Du 1022A of the Leura area and SL 346, SL 397, and SL 683 of the Strathmuir area. The fauna of SL 60 indicates only that it is in Fauna I or II. In the type area the Lizzie Creek Volcanics contain only Fauna I.

## Carmila Beds

### Fauna I

Du 179 — 7 miles northeast of Stoodleigh homestead. Grid ref. 271132, Saint Lawrence Sheet.

Brachiopods

Cancrinella farleyensis, Anidanthus springsurensis, Strophalosia cf. preovalis or jukesi, Ingelarella cf. profunda, and indet. spiriferoid.

Fenestellid bryozoans

Crinoid stems

Du 192 — 6 1/2 miles north of Stoodleigh homestead. Grid ref. 266134, Saint Lawrence Sheet.

Pelecypods

Deltopecten limaeformis

Brachiopods

Cancrinella sp., Cancrinella cf. farleyensis, Anidanthus springsurensis, Strophalosia cf. preovalis, Ingelarella profunda, Ingelarella cf. ovata, and Notospirifer sp. A.

Fenestellid bryozoans

Crinoid stems

Du 1000 — 1/2 mile south of Tooloombah homestead. Grid ref. 236164, Saint Lawrence Sheet.

Pelecypods

Eurydesma hobartense

Gastropods

Keeneia sp., Walnichollsia? sp. nov. A (Walnichollsia? sp. nov. in Dickins, 1966, and Dickins, Malone, & Jensen, 1964, is now referred to Walnichollsia? sp. nov. B).

Brachiopods

Strophalosia preovalis, Strophalosia cf. jukesi, and Notospirifer sp. A.

## Relationships

Du 192 and Du 1000 are linked by the occurrence of Notospirifer sp. A to Fauna I, found in the upper part of the Lizzie Creek Volcanics (previously Lower Bowen Volcanics) in the Mount Coolon Sheet area (Dickins, 1964a). Faunally Du 179 could represent either Fauna I or Fauna II. It is, however, in a similar position stratigraphically to Du 192 and is therefore included with Fauna I. Keeneia sp. from Du 1000 seems indicative of Fauna I or low Fauna II.

### Fauna I or Fauna II

Sl 397 In small creek, 1/2 mile west of Prospect Hills homestead. Grid ref. 230196, Saint Lawrence Sheet.

Pelecypods

Eurydesma hobartense and Deltopecten limaeformis.

Brachiopods

Cancrinella cf. farleyensis, Strophalosia preovalis (some specimens approach S. jukesi), and Aulosteges randsi.

Fenestellid bryozoans.

Sl 683 On Granite Creek 6 miles south of Amet Dale homestead. Grid ref. 232179, Saint Lawrence Sheet.

Pelecypods

Deltopecten limaeformis, Deltopecten cf. squamuliferus, and Streblopteria? sp. ind.

Gastropods

Keeneia sp.

Brachiopods

Terrakea pollex, Anidanthus springsurensis, Strophalosia sp. ind., Aulosteges? sp. ind., Neospirifer (Grantonia) cf. hobartensis, Ingalarella ovata, and Streptorhynchus?. sp. ind.

Du 2139 11 miles north-northeast of Leura homestead. Grid ref. 249129, Duaringa Sheet.

Brachiopods

Productids indet. and Neospirifer sp. ind.

Bryozoans and single corals

Du 2140 10 miles north-northeast of Leura homestead. Grid ref. 245129, Duaringa Sheet.

Pelecypods

Streblopteria sp. and Aviculopecten sp. ind.

Brachiopods

Cancrinella cf. farleyensis, Neospirifer sp. A, Ingelarella sp. ind., and a possible rhynchonellid.

Bryozoans.

## Relationships

The species present at these localities do not fall definitely into either Fauna I or Fauna II. The presence of Keeneia sp. suggests that SL 683 belongs to Fauna I or low Fauna II. Aulosteges randsi found at SL 397 may be confined to Fauna I, but the collections made so far give no definite indication of this.

## Back Creek Group

(1) Eastern Region

### Apis Creek Area

Du 745. 1/4 mile north of Bruce Highway, 2 miles west of Tooloombah turnoff. Grid ref. 235147, Saint Lawrence Sheet.

Pelecypods

Atomodesma sp., Modiolus sp.?, Aviculopecten sp., Streblopteria sp. (appears to be same as species in Fauna II at Homevale), Streblochondria? sp. (has fine radiating ribs), and Plagiostoma? sp. nov. (similar to species at Du 508, Thuriba area).

Gastropods

Peruvispira sp. (seems different from Peruvispira occurring in Fauna II at Homevale).

Brachiopods

Anidanthus springsurensis, Strophalosia preovalis, Neospirifer (Grantonia) cf. hobartensis, Ingelarella plana or I. ovata, and spiriferid indet.

Corals

Cladochonus sp. and single corals

Bryozoans

Fenestellids

Crinoids

Stem ossicles

Du 1017/2. 1/2 mile south of Bruce Highway at Apis Creek turnoff. Grid ref. 239146, Saint Lawrence Sheet.

Brachiopods

Cancrinella sp.

Du 1020. North of Bruce Highway, at Apis Creek turnoff. Grid ref. 238146, Saint Lawrence Sheet.

Pelecypods

Atomodesma (Aphanaia) sp.

Corals

Cladochonus sp. and a Favosites-like coral

Du 2158. 5 miles slightly west of north of Tartarus homestead. Grid ref. 222146. Saint Lawrence Sheet.

Brachiopods

Anidanthus springsurensis, and Ingelarella cf. plana or I. cf. ovata.

Corals

Cladochonus sp.

Bryozoans

Fenestellids and stenoporids

## Relationships

No conclusion on the position of Du 1017/2 or Du 1020 within the Permian sequence is possible on the basis of the fossils identified. Field information, however, suggests that Du 1020 is a few hundred feet stratigraphically above Du 745, so that it is considered together with Du 745. The relative position of Du 1017/12 is not clear, but for convenience it is considered with Du 745 and Du 1020.

Typical brachiopods of Fauna II are found at Du 745. Primary volcanics are associated with the fossil beds at Du 745, and vulcanism apparently continued in the Apis Creek area after it had ceased in the northern part of the Bowen Basin (Mackay, Mount Coolon, and Bowen Sheet areas).

The fossils from Du 2158 indicate that either Fauna I or Fauna II is represented at this locality.

### Fauna III or Fauna IV

Du 686. 5 miles north-northwest of Tartarus homestead. Grid ref. 221145, Saint Lawrence Sheet.

Pelecypods

Aviculopecten sp.

Gastropods

Mourlonia (Platyteichum) cf. costatum (apparently a juvenile specimen), and Peruvispira cf. imbricata.

Brachiopods

Cancrinella sp., Terrakea cf. solida, Strophalosia sp. nov. (as at Du 764 and in Ingelara Formation) or S. clarkei var. minima, Lissochonetes sp. ind., Ingelarella sp. ind., and Notospirifer cf. minutus.

## Relationships

The species of Mourlonia (Platyteichum), Peruvispira, Terrakea, Strophalosia, and Notospirifer indicate that this fauna is younger than Fauna II and represents Fauna III or Fauna IV - M. (P.) cf. costatum suggests Fauna III, whereas Terrakea cf. solida and N. cf. minutus suggest Fauna IV. All three, however, are represented by single specimens which are not sufficient for definite identification. In addition the specimen of M. (P.) cf. costatum is apparently a juvenile, and juveniles of P. costatum are difficult to distinguish from those of P. coniforme, which is found in Fauna IV. Probably the evidence falls in favour of Fauna IV, but no certainty is possible.

## Leura Creek Area

Fauna II

Du 7/2 Collection from float in Leura Creek, downstream from Leura homestead, Duaringa Sheet.

Brachiopods

Cancrinella sp., Anidanthus springsurensis, Strophalosia preovalis, Neospirifer sp. ind., Ingelarella cf. ovata, and Ingelarella cf. profunda.

Du 7/5 Collection from float in Leura Creek, near Leura homestead, Duaringa Sheet.

Brachiopods

Anidanthus springsurensis (Booker, 1932) and Neospirifer (Grantonia) cf. hobartensis (Brown, 1953).

Du 1022A. In Leura Creek, 7 miles northeast of Leura homestead. Grid ref. 251116, Duaringa Sheet.

Pelecypods

Eurydesma hobartense and Deltopecten limaeformis.

Gastropods

Keeneia sp.

Brachiopods

Ingelarella ovata, Ingelarella profunda, Notospirifer hillae, and Notospirifer sp. A?

Du 1022B. In Leura Creek, 7 miles northeast of Leura homestead. Grid ref. 251116, Duaringa Sheet.

Pelecypods

Modiolus sp.? and Deltopecten limaeformis.

Brachiopods

Strophalosia preovalis, Neospirifer sp. ind., and Ingelarella sp. ind.

Du 1022C. In Leura Creek, 7 miles northeast of Leura homestead. Grid ref. 251116, Duaringa Sheet.

Fenestellid bryozoans and brachiopod fragments.

Du 1022D. In Leura Creek, 7 miles northeast of Leura homestead. Grid ref. 251116, Duaringa Sheet.

Pelecypods

Conocardium sp.

Brachiopods

Anidanthus springsurensis, Strophalosia sp. ind., Lissochonetes sp., and Ingelarella cf. ovata.

Du 1030B. In tributary of Leura Creek, 6 1/2 miles northeast of Leura homestead. 1 mile south of locality Du 1022. Grid ref. 25115, Duaringa Sheet.

Pelecypods

Deltopecten cf. limaeformis

Brachiopods

Neospirifer sp. A?, Ingelarella ovata, and Ingelarella profunda.

EM 4/3. In headwaters of Leura Creek about 7 miles east-northeast of Leura homestead. Grid ref. 252115, Duaringa Sheet.

Brachiopods

Neospirifer sp. A, Ingelarella ovata, and Notospirifer hillae.

## Relationships

From faunal and stratigraphical data, all the samples from the Leura Creek area, with the possible exception of Du 1022A, apparently belong to Fauna II. Du 1022A is close to the base of the Back Creek Group. Four of the species identified at Du 1022A are common to Faunas I and II. From information considered later Keeneia sp. suggests Fauna I or low Fauna II. If Notospirifer sp. A is indeed present, Du 1022A may belong to Fauna I rather than Fauna II.

EM 4/3 was collected later than the main fossil material and the prefix EM refers to collections made by E.J. Malone.

## Saint Lawrence (Township) Area

### Fauna I or Fauna II

Sl 346. About 1 mile north of Saint Lawrence/Croydon road, on road to Ripplebrook homestead. Grid ref. 225209, Saint Lawrence Sheet.

Pelecypods

Astartila? sp., Deltopecten limaeformis, Aviculopecten sp. (simple form as in Fauna I), and Stutchburia sp. ind.

Gastropods

Keeneia sp.

Brachiopods

Cancrinella sp., Strophalosia preovalis, Aulosteges? sp. ind., Neospirifer (Grantonia) cf. hobartensis, Trigonotreta cf. sp. A., and Cancellospirifer sp.

SL 370. In railway cutting 2 miles south of Saint Lawrence; in nodular or concretionary siltstone. Grid ref. 234208, Saint Lawrence Sheet.

Brachiopods

Cancrinella farleyensis.

Conulariids

Sponge spicules

## Relationships

The species present at these localities are not definitive of either Fauna I or II.

## Connors River area

Fauna II

SL 603. In Main Range Creek, 1/2 mile west of Bruce Highway. Grid ref. 171248, Saint Lawrence Sheet.

Pelecypods

Deltopecten limaeformis.

Brachiopods

Cancrinella farleyensis, Anidanthus springsurensis, Strophalosia preovalis, Neospirifer (Grantonia) cf. hobartensis, Trigonotreta sp. A, Ingelarella ovata, and Cancellospirifer? sp.

Ostracods

SL 608. One mile west-northwest of Saltbush Park turnoff from the Bruce Highway. Grid ref. 174240, Saint Lawrence Sheet.

Pelecypods

Aviculopecten sp. and Streblopteria sp.

Gastropods

Peruvispira sp. [not comparable with P. allandalensis (Fletcher, 1958), but may be comparable with P. elegans (Fletcher, 1958)].

Brachiopods

Cancrinella farleyensis, Anidanthus springsurensis, Strophalosia preovalis, Lissochonetes sp., Neospirifer (Grantonia) cf. hobartensis, Ingelarella ovata, Ingelarella profunda, and dielasmatids.

Corals

Cladochonus sp.

Conulariids, fenestellid bryozoans, and a straight nautiloid.

SL 610. 1 mile south of the Main Range Creek, on the Bruce Highway, east side of road. Grid ref. 172247, Saint Lawrence Sheet.

Gastropods

Mourlonia (Mourlonia) sp. nov.

SL 643. 1 mile east of Bruce Highway, hill on south side of Yatton Creek, 'Yatton Limestone'. Grid ref. 207188, Saint Lawrence Sheet.

Pelecypods

Streblopteria? sp. ind. and Cypricardinia? sp.

Brachiopods

Cancrinella farleyensis, Anidanthus springsurensis, Strophalosia preovalis, Neospirifer sp. A., Ingelarella ovata, and Pseudosyrinx sp.

Corals

Cladochonus sp. and single corals

Fenestellid bryozoans

Relationships

None of the fossils collected from the Connors River area is younger than Fauna II. The samples from SL 603 and SL 608 are definite Fauna II, and SL 610 was collected at a similar stratigraphical position. Although, from field evidence, SL 643 appears to be slightly lower stratigraphically than the other three samples, the fossils identified also seem to represent Fauna II.

(2) Folded Zone

Gebbie Subgroup

Fauna III

Du 147b. 1 1/2 miles west of Bundaleer homestead. Grid ref. 181125, Duaringa Sheet.

Pelecypods

Astartila cf. gryphoides and Notomya or Pyramus sp. (appears to be same species as in Fauna IIIb at B261d of Bowen Sheet area).

Du 149. North bank of Mackenzie River, 1 1/2 miles southwest of Bundaleer homestead. Grid ref. 183125, Duaringa Sheet.

Pelecypods

Chaenomya sp. nov. B?

Gastropods

Mourlonia (Platyteichum) costatum?

This locality also contains glendonites.

Du 149a. Float collection from near outcrop, north bank of Mackenzie River, 1 1/2 miles southwest of Bundaleer homestead. Grid ref. 182124, Duaringa Sheet.

Pelecypods

Chaenomya sp. nov. B.

Single coral

Du 150. 1 mile south-southwest of Bundaleer homestead. Grid ref. 183125, Duaringa Sheet.

Atomodesma (Aphanaia) sp.

Du 151. 1 mile southwest of Bundaleer homestead. Grid ref. 183125, Duaringa Sheet.

Pelecypods

Glyptoleda or Phestia sp. and Conocardium sp.

Brachiopods

Cancrinella magniplica [1], Attenuatella sp. nov. [2] and Plekonella acuta.

Du 151a. 1 mile southwest of Bundaleer homestead. Grid ref. 183125, Duaringa Sheet.

Pelecypods

Nuculopsis (Nuculopsis) sp. and Glyptoleda? sp.

Brachiopods

Ingelarella angulata Campbell, 1959.

Du 286. 1 1/4 miles west of Bundaleer homestead. Grid ref. 182125, Duaringa Sheet.

Pleurotomariid gastropod, straight nautiloid?, serpulids, and large single corals.

Du 764. 2 miles west-northwest of Bundaleer homestead. Grid ref. 181126, Duaringa Sheet.

Pelecypods

Parallelodon sp. (specimens not very satisfactory but radial ribs seem to be of one order and therefore differs from Parallelodon sp. nov. B. of Fauna IV in which the ribs behind the posterior carina are coarser that those on the body of the shell), Atomodesma? sp., and Conocardium sp.

Gastropods

Bembexia sp.

Brachiopods

Cancrinella magniplica, Strophalosia sp. nov. (this probably new species is flatter than S. preovalis or S. brittoni and the valves are wider than in S. clarkei. It is most closely related to specimens from the Ingelara Shale), Lissochonetes sp., Ingelarella ingelarensis, Attenuatella sp. nov., and Plekonella cf. acuta.

Large single coral.

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1

The specimens from this sample and from Du 764 identified as Cancrinella magniplica vary considerably in their transverse ribbing. Some have less pronounced ribbing (or wrinkling) similar to that shown by Campbell (1953, pl. 1, figs 1-5) - others show more distinct wrinkling as in pl. 1, figs 6-8.

2

Attenuatella is a genus recently described and named by Stehli (1954, p. 343) from the Lower Permian of North America. I am grateful to K.S.W. Campbell for identifying these specimens as Attenuatella.

EM 11/1. 1 mile southwest of Bundaleer homestead. Grid ref. 183125, Duaringa Sheet.

Brachiopods

Neospirifer sp. ind. and Plekonella sp. ind.

EM 11/2. 1 mile southwest of Bundaleer homestead. Grid ref. 183125, Duaringa Sheet.

Brachiopods

Ingelarella cf. ingelarensis.

## Relationships

All these samples are close together stratigraphically. Du 149, Du 151, Du 286, Du 764, EM 11/1, and EM 11/2 come from a siltstone and grey sandstone unit with rounded concretions and glendonites, which immediately overlies a sandy unit, forming the oldest rocks exposed in the Folded Zone, with Du 147b, Du 149a, Du 150, and Du 151a. The unit is in turn overlain by another sandy unit in which no fossils were seen.

Cancrinella magniplica, Ingelarella ingelarensis, I. angulata, and Plekonella acuta are known from the Ingelara Formation, as are the specimens most closely related to Strophalosia sp. nov. Cancrinella magniplica, Ingelarella ingelarensis, and I. angulata, which may be found in younger beds, are not known in beds older than Fauna III.

Astartila cf. gryphoides and Bembexia sp., which are also found in Fauna II, are not known in beds younger than Fauna III, and Notomya or Pyramus sp. and Chaenomya sp. nov. B are known only in Fauna III. Fauna III is therefore represented. Hitherto brachiopods have been poorly represented in Fauna III, whereas they are plentiful in Faunas II and IV. The fauna from these localities links the brachiopod-rich Ingelara Formation with Fauna III.

## Blenheim Subgroup

Du 283. 3 miles northeast of Barwon Park homestead. Grid ref. 168129, Duaringa Sheet.

Brachiopods

Cancrinella sp. ind. and Ingelarella cf. ingelarensis.

Du 383C. 12 miles southeast of Foxleigh homestead. Grid ref. 165133, Saint Lawrence Sheet. The matrix of the fossils is very sandy.

Brachiopods

Strophalosia cf. ovalis, Neospirifer sp. B, Ingelarella cf. mantuanensis, Notospirifer minutus, Cancellospirifer sp., Plekonella sp., and Streptorhynchus pelicanensis.

Single corals

Du 383D. 12 miles southeast of Foxleigh homestead. Grid ref. 165133, Saint Lawrence Sheet.

Brachiopods

Terrakea cf. solida.

Du 385. 12 miles southeast of Foxleigh homestead. Grid ref. 166144, Saint Lawrence Sheet.

Brachiopods

Strophalosia cf. brittoni var. gattoni, Neospirifer sp. B, Notospirifer sp. ind., Cancellospirifer sp., and Streptorhynchus pelicanensis.

Du 387. 13 miles southeast of Foxleigh homestead. Grid ref. 166133, Saint Lawrence Sheet.

Brachiopods

Strophalosia cf. clarkei, Strophalosia cf. ovalis, and Streptorhynchus pelicanensis.

Single corals and fenestellid bryozoans.

Du 424. 8 miles north of Warwick homestead. Grid ref. 139178, Saint Lawrence Sheet.

Pelecypods

Megadesmus cf. grandis, Notomya sp. (similar to species at CL 122 of the Clermont Sheet area), Stutchburia compressa, and Astartidae gen. nov. sp? (appears to be closer to species of Fauna IV than of Fauna III).

Gastropods

Warthia sp. and Mourlonia (Platyteichum) cf. coniforme.

Du 469. 4 miles east-southeast of Warwick homestead. Grid ref. 144164, Saint Lawrence Sheet.

Brachiopods

Strophalosia sp. ind., Ingelarella angulata, I. cf. havilensis, and Trigonotreta? sp. Crinoid stem ossicles.

Du 472. 3 miles east of Warwick homestead. Grid ref. 143167, Saint Lawrence Sheet.

Pelecypods

Glyptoleda cf. glomerata.

Gastropods

Warthia sp. and Mourlonia (Mourlonia) cf. strzeleckiana.

## Relationships

The field relationships suggest that these localities are in the Blenheim Subgroup, which contains Fauna IV. Definite Fauna IV is indicated in Du 383C, Du 385, and Du 387, and the faunas of Du 383D, Du 424, and Du 469 are suggestive of Fauna IV. Du 283 and Du 472 could contain Fauna III or Fauna IV. Du 283 is, apparently, slightly higher stratigraphically than the Du 383 localities.

The presence of Streptorhynchus pelicanensis in Du 383C, Du 385, and Du 387 suggests that these samples are from, in a general way, the equivalent of the Streptorhynchus pelicanensis Bed of the Blenheim Subgroup of the Collinsville area. These beds are also in a general way probably equivalent to the pelecypod bed of the Clermont Sheet area (see Veevers, Randal, Mollan, & Paten, 1964), which has a similar fauna and is found in a similar stratigraphical position to the Streptorhynchus pelicanensis Bed. S. pelicanensis, however, is poorly represented in the Clermont area.

Du 383C, Du 385, and Du 387, the pelecypod beds, and the Streptorhynchus pelicanensis Bed are all sandy and are similar lithologically and faunally to fossiliferous beds in the Western Region (Comet area) considered in the next section, which are included in the Crocker Formation (Derrington & Morgan, 1959, and in Hill & Denmead, 1960, p. 207).

Du 383D is a coquinite and possibly represents the clarkei bed of the Clermont area; its field relationships suggest that it comes from a slightly lower stratigraphical position than Du 383C.

(3) Western Region

Du 519. 3 miles east-southeast of Myrtle Park homestead. Grid ref. 133053, Duaringa Sheet.

Gastropods

Peruvispira sp. ind.

Brachiopods

Terrakea solida, Neospirifer sp. B, Ingelarella cf. havilensis, I. pelicanensis, and Streptorhynchus pelicanensis.

Wood

Large single coral

Du 1214. 9 miles east of Rhudanna homestead. Grid ref. 145050, Duaringa Sheet. Sandstone with pebbles up to 1/2".

Brachiopods

Terrakea solida, Neospirifer sp. B, Ingelarella mantuanensis, Notospirifer minutus, Streptorhynchus cf. pelicanensis, and a flat dielasmatid.

Single coral.

Relationship

These two collections are from the Crocker Formation and represent Fauna IV. The occurrence of Ingelarella pelicanensis and Streptorhynchus pelicanensis suggests an horizon equivalent or close to the Streptorhynchus pelicanensis Bed of the Collinsville area. The equivalent of the Big Strophalosia Zone has not been identified so far in this area.

Du 85. In German Creek, at western margin. Grid ref. 119139, Saint Lawrence Sheet.

Brachiopods

Ingelarella cf. ingelarensis.

Crinoid stem ossicles and cup.

Du 890. 5 miles northwest of Carnangarra homestead. Grid ref. 134084, Duaringa Sheet.

Pelecypods

Atomodesma (Aphanaia) sp.

## Relationships

The few fossils found at these last two localities are not characteristic forms.

(4) Thuriba Area

Du 158. Beside power line, 2 miles southwest of Thuriba homestead, Baralaba Sheet.

Pelecypods

Plagiostoma? sp. nov.

Brachiopods

Neospirifer sp. A, Ingelarella cf. ingelarensis, Licharewia? sp.

Bryozoans

Branching stenoporoids

Du 159. 1 1/2 miles southwest of Thuriba homestead. Grid ref. 285012, Duaringa Sheet.

Corals

Thamnopora sp. and Cladochonus sp.

Du 508. 3 1/2 miles northwest of Thuriba homestead. Grid ref. 281017, Duaringa Sheet.

Pelecypods

'Modiolus' sp. ind. and Plagiostoma? sp. nov.

Brachiopods

Strophalosia cf. clarkei var. minima (wide with moderately well developed muscle platform in pedicle valve), Ingelarella cf. ingelarensis or mantuanensis, Licharewia? sp., a punctate or spinose spiriferoid, and a terebratuloid.

Stenoporoid bryozoans

Corals

Cladochonus sp.

Du 510. 4 1/2 miles northwest of Thuriba homestead. Grid ref. 279018, Duaringa Sheet.

Stenoporoid bryozoans

Corals

Thamnopora sp.. and Cladochonus sp.

Du 511. 3 miles west-northwest of Thuriba homestead. Grid ref. 281015, Duaringa Sheet.

Pelecypods

Atomodesma (Aphanaia) sp. (as in Oxtrack Formation), Aviculopecten sp., Streblopteria sp. ind., and Astartila or Astartidae.

Brachiopods

Terrakea cf. solida, Cancrinella cf. magniplica, Neospirifer sp. A, Ingelarella cf. mantuanensis, and Cancellospirifer? sp.

Fenestellid bryozoans, single corals, and crinoid stems.

Ba 825. 4 miles north-northwest of Thuriba homestead. Grid ref. 282021, Duaringa Sheet

Stenoporoid bryozoans.

Corals

Cladochonus sp.

Indeterminate brachiopod shells

Ba 827. 3 1/2 miles north-northwest of Thuriba homestead. Grid ref. 284020, Duaringa Sheet.

Brachiopods

Ingelarella cf. plana or mantuanensis, and brachiopod fragments.

## Relationships

All the localities are close together stratigraphically and on the basis of the faunas from the Baralaba, Monto, and Mundubbera Sheet areas, the marine fossils from the Permian of the Thuriba area are not older than the Oxtrack Formation, as restricted by Jensen, Gregory, & Forbes (1964). Similar faunas are found at all the localities, and in the Bowen Basin Atomodesma (Aphanaia) sp. from Du 511 is only known from the Oxtrack Formation and in the Clermont area (i.e. it is confined to Fauna IV). All the species, as far as they can be identified, are found in the Oxtrack Formation and higher beds in the area to the south. The occurrence of Cancrinella cf. magniplica in beds younger than the Ingelara Formation is discussed in the report on the fossils from the Monto and Mundubbera Sheet areas (Dickins in Jensen et al., 1964). R.E. Wass has examined the bryozoans from Du 158, Du 508, and Du 510, and considers (in a letter) that those from Du 508 and Du 510 are 'similar to those found in the Oxtrack Formation'. Those from Du 158 were too weathered for identification.

Lithologically Du 158, Du 508, Du 511, Ba 825 and Ba 827 fall within the limits of the Oxtrack Formation, but Du 510 is found associated with dark siltstone and tuffaceous beds similar to the Barfield Formation. As shown elsewhere (Dickins, op. cit.), the faunas of the Oxtrack and Barfield Formations are closely related and belong to Fauna IV.

## CONCLUSIONS

### General

The new collections have confirmed the distinctiveness of Fauna I. Although many of the brachiopods are found also in Fauna II, Notospirifer sp. A appears to be confined to Fauna I. Keeneia sp., although it ranges into Fauna II, is common, as is Strophalosia of the S. jukesi type. 'Megadesmus' cf. antiquata appears to characterize Fauna I, but the range of Aulosteges randsi and the significance of Deltopecten cf. illawarensis are not clear.

The correlation of the faunas from the Bowen Basin with those from the Hunter Valley, New South Wales, and their age is discussed elsewhere (Dickins, 1960 and in press). The evidence from this area gives no indication that Fauna I is greatly older than Fauna II, and, from the large number of species the two have in common, this seems unlikely.

The relationships of the faunas from the Bowen Basin with those farther south in the Yarrol Basin (Maxwell, 1964) is not clear.

Rannes Beds (?)

The single species present would suggest Permian age. Reservation, however, is necessary on the assignment of this outcrop to the Rannes Beds.

Lizzie Creek Volcanics

Of the four localities from this formation, one appears to have Fauna I, two Fauna I or low Fauna II, and the fossils from the fourth indicate only that Fauna I and II are represented. Elsewhere only Fauna I is found in the Lizzie Creek Volcanics (Dickins, 1964) and it is possible that in this area also the four localities contain Fauna I.

Carmila Beds

Two of the six localities contain Fauna I; the other four contain Fauna I or Fauna II. Like the Lizzie Creek Volcanics, it is possible that only Fauna I is represented in the Carmila Beds.

Back Creek Group

(1) Eastern Region

In order to test the conclusions made in this Report, the collections from this area in the Geological Survey of Queensland have also been examined.

Apis Creek Area. With the exception of two localities, it appears that only Fauna II is represented. A similar fauna has also been recorded by Laing & Hill in Hill & Denmead (1960, p. 221) and by J.T. Woods in unpublished reports to Reef Oil Pty Ltd.

In the Survey a collection labelled 'Mt Brunswick' was examined. At Mount Brunswick the Permian is immediately overlain by Cretaceous. The fauna contains Atomodesma (Aphanaia) sp., Strophalosia preovalis, and an indeterminable species of Anidanthus and is therefore not younger than Fauna II.

One exceptional locality is Du 686, which contains Fauna III or Fauna IV. The specimens from the other, 3/4 mile southeast of Kooltandra Railway Station, Saint Lawrence Sheet, are in the Geological Survey of Queensland. Species of Astartila or Astartellidae, Chaenomya, and Terrakea are contained in a quartzose sandstone. The fauna appears to be younger than Fauna II and may represent Fauna III.

Leura Creek Area. The collections appear to belong to Fauna II, with the possible exception of Du 1022A. This locality is close to the base of the Back Creek Group and if Notospirifer sp. A is present may contain a Fauna I.

Saint Lawrence (Township) Area. Either Fauna I or Fauna II or both are represented by the two localities in this area.

Connors River Area. None of the fossils collected is younger than Fauna II. The palaeontological and stratigraphical information suggests that only Fauna II is represented. The beds can be referred to the Tiverton Subgroup as defined to the north.

(2) Folded Zone

Gebbie Subgroup

Fauna III is the oldest fauna found in the Folded Zone. Here molluscs of Fauna III are associated with brachiopods characteristic of the Ingelara Formation, giving an indication that the fauna of the Ingelara is Fauna III.

Blenheim Subgroup

It is probable that the clarkei bed (= Big Strophalosia Zone) and the equivalent of the Streptorhynchus pelicanensis Bed of the Collinsville area are present. This gives an indication that the pelecypod bed, which overlies the clarkei bed in the Clermont area, may be equivalent to the Streptorhynchus pelicanensis Bed, although Streptorhynchus is poorly represented in the Clermont area.

(3) Western Region

The fossils are from the Crocker Formation and suggest that this formation is close in age to the Streptorhynchus pelicanensis Bed of the Collinsville area.

(4) Thuriba Area

Rocks with Fauna IV rest with a break on a sequence which is older than the Back Creek Group. The Oxtrack Formation is the lowest formation of the sequence above the break. It is overlain by siltstone similar to that of the Barfield Formation.

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## APPENDIX II

## PLANT FOSSILS FROM THE DUARINGA AND SAINT LAWRENCE SHEET AREAS

by

Mary E. White

(Collections are grouped under formations and the description of each locality includes the grid reference )

### Styx Coal Measures

Locality DU971, 10 miles WNW of Redbank homestead (263126, Duaringa Sheet).

Specimens F22289: *Taeniopteris* cf. T. *spatulata* var. *major* Seward, *Taeniopteris spatulata* McClell, *Cladophlebis australi* Morr.
Age: Jurassic or Lower Cretaceous.

### Rewan Formation

Localities DU291a and DU290C, at head of Springton Creek about 14 miles SSW of Dingo (209028, Duaringa Sheet).

Specimens F22178: Fragmentary plant remains. The following are tentatively identified: Equisetalean stems, *Danaeopsis* sp.? seed, cone, scale, *Linguifolium denmeadi*?, Conifer foliage, *Dicroidium feistmanteli*?
Age: Although the specimens are poor, the weight of evidence suggests Triassic age.

### BLACKWATER GROUP

Locality DU5, 3 miles ESE of Barwon Park homestead (168124, Duaringa Sheet).

Specimens F22292: *Glossopteris angustifolia* Bgt., *G. indica* Sch., *G. conspicua* Feist., *G. ampla* Dana, *Cladophlebis roylei* Arber.

Locality EM3/1, in Mackenzie River, 3 miles North of Bingegang homestead (175121, Duaringa Sheet).

*Glossopteris conspicua* Feist., *G. ampla* Dana, *G. indica* Sch., *G. angustifolia* Bgr; *Glossopteris* scale leaves of the large, thick variety with reticulated pattern on surface, believed to be of *Glossopteris ampla*; *Vertebraria indica* Royle, *Cladophlebis roylei* Arber, and equisetalean stems.

Locality EM13/2, in Mackenzie River, 3 miles N of Bingegang homestead (175121, Duaringa Sheet).

*Glossopteris conspicua* Feist., *G. ampla* Dana, *G. communis* Feist., *G. indica* Sch., *G. damudica* Feist., *G. tortuosa* Zeiller, *G. angustifolia* Bgr., and scales of *Glossopteris ampla*; *Dictyopteridium sporiferum*, a male fructification such as occurs with *Glossopteris communis* in Upper Permian at Baralaba; *Cladophlebis roylei* Arber, and equisetalean stems.

Part of a leaf of Taeniopteris sp. is present. This is interesting as there are only a few authenticated cases of Taeniopteris associated with Glossopteris and this is the first record of the association in the Upper Permian of the Bowen Basin (Pl. A, fig. 2).

Locality DU262, 5 miles N of Melmoth homestead (206086, Duaringa Sheet).

Specimens F22172: Glossopteris angustifolia Bgt., G. indica Sch., G. conspicua Feist., Cladophlebis roylei Arber.

Locality DU265, 7 miles SE of Melmoth homestead (214067, Duaringa Sheet).

Specimens F22179: Equisetalean stems; ?Glossopteris fragment.

Locality DU279, 1 mile NE of Melmoth homestead, (207077, Duaringa Sheet).

Specimens F22173: Glossopteris angustifolia Bgt., G. conspicua Feist., modified leaves and scale leaves of G. angustifolia, Vertebraria indica Royle, equisetalean stems.

Locality DU756, 4 miles SSE of Melmoth homestead (208071, Duaringa Sheet).

Specimens F22174 and F22174(a): Glossopteris indica Sch., G. angustifolia Bgt., G. conspicua Feist., G. jonesi Walk., Cladophlebis roylei Arber, G. damudica?, 'Dictyopteridium sporiferum', a male Glossopteris fructification.

F22174(a): Taeniopteris sp.?

Glossopteris jonesi Walk. is a species very close to Taeniopteris. The taeniopteroid tendency occurs in Upper Permian Glossopteridae. The Taeniopteris sp.? identified in specimen F22174 (a) might possibly be only the midsection of a leaf of G. jonesi.

The presence of taeniopteroid forms and G. conspicua indicates Upper Permian age.

The 'Dictyopteridium sporiferum' is a long, narrow organ whose surface is covered with circular sporangia. It is the same as examples from the Baralaba Coal Field which occur with Cistella bowenensis sp. nov. (White, MS.), and may also be regarded as indicating Upper Permian age.

Locality DU758, at Melmoth homestead (206076, Duaringa Sheet).

Specimens F22282 and F22283: Glossopteris indica Sch., G. angustifolia Bgt., Vertebraria indica Royle; equisetalean stems; 'Dictyopteridium sporiferum' Feist. of the same type as is associated with Cistella bowenensis sp. nov. (M.E.W., MS.) from Baralaba, Queensland; Glossopteris damudica?

Locality DU760c, 3 miles NNW of Melmoth homestead (080204, Duaringa Sheet).

Specimens F22175: Equisetalean stems

Locality DU775, 6 miles W of Melmoth homestead (195076, Duaringa Sheet)

Specimens F22116: Cladophlebis roylei Arber, G. angustifolia Bgt., G. conspicua Feist.
Age: Upper Permian

Locality DU795, 5 miles NW of Melmoth Homestead (200083, Duaringa Sheet).

Specimens F22177: Glossopteris angustifolia Bgt., G. indica Sch., Cladophlebis roylei Arber.
Age: Permian

## Boomer Formation

Locality DU163e, 3 miles ENE of Rio homestead (277032, Duaringa Sheet).

Specimens F22280: Noeggerathiopsis hislopi (Bund.)? The specimen is poor and the determination is tentative. However, the impression appears to be of the type of Noeggerathiopsis hislopi characteristic of the Lower Permian basin sediments. (See note on Noeggerathiopsis, p. 124.)

Age: ?Lower Permian, or Upper Carboniferous

Locality DU1230, 1.5 miles SSE of Foley Vale homestead (257069, Duaringa Sheet).

Specimens F22291: Indeterminate plant remains.

## German Creek Coal Measures

Locality DU520, 6 miles ENE of Comet (136060, Duaringa Sheet).

Specimens F22281: These specimens are very poor. A narrow leaf with parallel margins and a well defined midrib and fine secondary venation of Glossopteris type is probably referable to Glossopteris angustifolia Bgt., a long-ranging Permian form.

Locality DU873, 3.5 miles NE of Old Mt Stuart homestead (140109, Duaringa Sheet).

Specimens F22288 (Bulk of collection), F22285, F22286, and F22287 (figured specimens): Glossopteris ampla Dana, G. conspicua Fm., G. indica Sch., Cistella ampla sp. nov.

Age: Upper Permian

The specimens from this locality are most beautifully preserved and of great interest. Very large leaves of Glossopteris ampla are present in large numbers. A few small leaves of G. conspicua and two medium-size leaves which may be G. indica are also present. Cone-like fructifications, some complete, and many more or less fragmentary, occur on many of the specimens. These are referred to Cistella ampla sp. nov. They are believed to be the fructifications of Glossopteris ampla.

Details of the specimens from which the description of the new species will be compiled for publication are as follows:

Specimen F 22285: Part of the oval cone-like body 3.5 cm long and 3 cm wide is present. A stem 0.6 cm wide and 0.8 cm long enters the base of the cone. The surface of the cone is regularly pitted with pear-shaped depressions averaging 0.5 cm long and 0.4 cm wide. Each appears to contain a seed of Nummulospermum bowensis Walk. type. There are about 50 such depressions on the cone. Large leaves of Glossopteris ampla are associated. Plate A, figure 1, shows the fructification and leaves.

Specimen F22286: Two fructifications are present on this specimen with large leaves of Glossopteris ampla and with many seeds from the fructifications separately preserved. Plate B, figure 1 shows a cone in which a smooth leaf-like layer covers the sacs (or pits), whose presence underneath is revealed by bumps and depressions. At the point marked by an arrow in the figure, the surface-covering layer has been chipped away and the sacs are seen as three-dimensional bodies. The fructification was obviously fleshy and bulky. Plate B, figure 2 shows a very large fructification. Dimensions (of the incomplete body) are 7 X 5 cm. The very numerous sacs average 0.5 X 0.4 cm. An area of smooth wing 0.5 cm wide is seen on the right side of the cone, a narrower wing on the opposite side. Plate B, figure 3 shows seeds free in the rock matrix. Each has the same dimensions and the same markings as the sac-contents on complete fructifications.

PLATE A

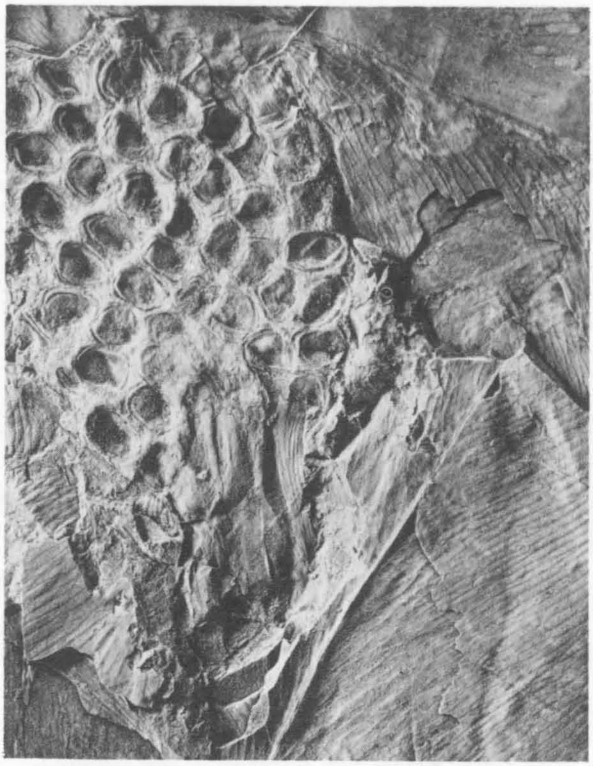

Fig. 1 : Cistella ampla sp. nov. Specimen F22285. Fructification showing sacs containing seeds. Leaves of Glossopteris ampla Dana (magnification x2).

Fig. 2 : Taeniopteris sp. associated with Glossopteris. Collection EM 13/2, Blackwater Group, north of Bingegang homestead, Duaringa 1:250,000 Sheet area.

PLATE B

Fig. 1

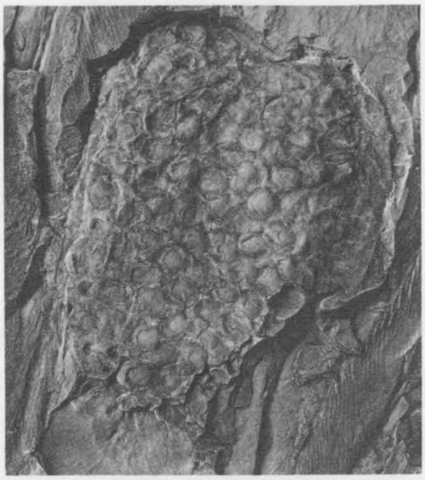

Fig. 2

Fig. 3

Fig. 4

Cistella ampla sp. nov. (natural size)
Figs 1, 2, 3, Specimen F22286; Fig. 4, Specimen F22287.

Specimen F22287: Plate B, figure 4 shows a pear-shaped fructification 7 cm long and 4 cm wide at the broadest part. The left side of the cone is covered by the smooth leaf-like tissue seen in figure 2, the right side shows sacs on the surface, and in particular a row of marginal sacs 0.5 cm deep.

Interpretation of the fructifications: There is no fluted wing around the fructification such as occurs in Scutum. The fructification appears to be two-sided - the one showing the sacs, and the other a leaf-like cover. In examples seen from the sac-covered side, the smooth wing beyond the marginal sacs is probably the projecting edge of the leaf-like covering part. The fructification is therefore of the type referred to Cistella Plumstead, and the name Cistella ampla is proposed because of the strong possibility that the fruits belong to the leaves with which they are associated.

Undifferentiated Back Creek Group

Locality DU829, 12 miles NE of Leura homestead (250129, Duaringa Sheet).

Specimens F22284: Equisetalean stems.

Carmila Beds

Locality M68, 5 miles NW of Marlborough (269162, St Lawrence Sheet).

Specimens F22608: Leaves of Noeggerathiopsis hislopi (Bunb.) are associated with equisetalean stems and indeterminate plant fragments. Some of the leaves are of the coarse variety of Noeggerathiopsis regarded as typical of Upper Carboniferous and Lower Permian strata.

Locality M72, 7.5 miles NNW of Marlborough (271168, St Lawrence Sheet).

Specimens F22609: Leaves of Noeggerathiopsis hislopi (Bunb.) are associated with leaves of Glossopteris indica Sch. type. The Noeggerathiopsis leaves are not of the type confined to Lower Permian, but of the finer type which range throughout the Permian. Some of the Glossopteris leaves are of the coarse variety with strong vertical striation of the midrib most characteristic of Lower Permian assemblages.

Locality M89, 5 miles ENE of Burwood homestead (226191, St Lawrence Sheet).

Specimens F22610 and F22611: Numerous leaves of Noeggerathiopsis hislopi (Bunb.) are present. Many of these are of the coarse variety typical of Lower Permian horizons. A few leaves of Glossopteris indica Sch. type are associated. Young examples show normal venation of the species. One very large example has the coarsely stranded midrib often seen in Lower Permian leaves of this type. Part of a leaf probably referable to Gangamopteris cyclopteroides Feist. is identified. This species is typically Lower Permian, becoming increasingly rare in higher Permian horizons.

Locality M95, 6 miles SW of Tooloombah homestead (230156, St Lawrence Sheet).

Specimens F22612: Noeggerathiopsis hislopi (Bunb.), G. indica Sch., G. ampla Dana, Gangamopteris cyclopteroides Feist.

Locality SL241, 3 miles W of Amet Dale homestead (229190, St Lawrence Sheet).

Specimens F22299: Noeggerathiopsis sp.?

Locality SL410, 1.5 miles NNW of Elalie railway station (229250, St Lawrence Sheet).

Specimens F22300: Very large numbers of leaves of 'Noeggerathiopsis hislopi (Bunb).' are present, ranging in size from small, complete leaves about 4 cm long and 1 cm broad at the widest part, tapering to a narrow petiolar region, through complete leaves about 10 cm long and 4 cm wide at the widest part, to incomplete leaves, some with very coarse venation, of unknown length with breadth at least 8 cm. Associated with these leaves are very large seeds of Samaropsis dawsoni (Shirley) type which measure about 2.5 cm long and 2 cm broad near the base. These pear-shaped seeds show a divided apex and appear to have had a narrow wing. There is a strong possibility that these specimens are the seeds of Noeggerathiopsis hislopi.

'Noeggerathiopsis hislopi' of this type is characteristic of the Lower Permian of the Bowen Basin and does not occur with the typical Upper Permian species. Dr Plumstead, in a recent 'Review of the Permo-Carboniferous Coal Measures of the Transvaal, South Africa' states that Noeggerathiopsis hislopi is 'a survival of a pre-Glossopteris flora, which may be regarded as indicative of the earliest period of Gondwana coal formation, and if the Argentine dating is acceptable, as of a late Carboniferous age'.

In view of Dr Plumstead's remarks, it is possible that a pure assemblage of Noeggerathiopsis with its (?) seeds might be of Upper Carboniferous age. If locality SL410 is at the base of the Carmila Beds it might indicate that the sediments were low down from Upper Carboniferous and continued into Lower Permian. However, if the age of the beds is known to be younger than Lower Permian volcanics, a Lower Permian age is indicated.

Age:, A Lower Permian, or Upper Carboniferous to Lower Permian, age is suggested by plant evidence.

Youlambie Conglomerate

Locality DU1212, 6 miles SSE of Armagh homestead (287089, Duaringa Sheet).

Specimen F22290: Noeggerathiopsis hislopi (Bunb.)

Age: Lower Permian. The Noeggerathiopsis is of the type present in Lower Permian beds.

Note on Noeggerathiopsis hislopi (Bunb.)

'Noeggerathiopsis hislopi (Bunb.)' is a form-species name given to leaves which exhibit strongly parallel venation. Many shapes and sizes of leaf are involved. Long, narrow leaves, similar to monocotyledon leaves in modern floras (in general appearance), are most strictly referable to the species. Many broader examples with nearly parallel margins which taper towards the leaf base are also included. However, some broad leaves are found in Lower Permian and Upper Carboniferous horizons in Australia and South Africa, with strong parallel venation, which have been referred to the species in the past for want of any better name to use. One such leaf is known as Palaeovittaria kurzi, which has been described bearing Glossopteris-type fructifications in the Lower Permian of South Africa.

It is impossible to define exactly when a coarse-parallel-veined leaf shows sufficient divergence in the veins from strictly parallel formation to warrant inclusion in Palaeovittaria kurzi. Usually preservation of leaves is of impression type with only major features of secondary venation visible and no detail of cell or stomata structure to assist.

Characteristic of the Lower Permian of the Bowen Basin are large numbers of coarsely veined more or less parallel-veined leaves. They differ very markedly from the most typical long narrow parallel-veined leaves of 'Noeggerathiopsis hislopi' such as occur in the Greta Coal Measures as well as in the Upper Coal Measures in New South Wales. Wherever there is a record of an Upper Permian or even a Triassic occurrence of the species it involves leaves of the latter type, not of the type characteristic of the Lower Permian.

It seems probable that the Lower Permian type of 'Noeggerathiopsis' is not justifiably referred to the genus and not in any way connected with the Cordaitales. It is much more likely that it is related to the Glossopteridae and to the '*Palaeovittaria kurzi*' which bears glossopterid fructifications in South Africa. It is doubtful, however, if there is a good case for using the name '*Palaeovittaria*' in this instance. Some advanced glossopterids (cf. *mitchelli* etc.) in Upper Permian horizons have evolved towards *Taeniopteris* and are now referred to as *Palaeovittaria*.

In identification of leaves in recent BMR collections I have referred to *Noeggerathiopsis hislopi* 'of Lower Bowen type' and have determined Lower Permian or Upper Carboniferous age for the fossil horizons. I am not aware of any example of *Noeggerathiopsis hislopi* 'of Lower Bowen type' which occurs in Upper Permian strata, and have hopes that the type is confined to the earliest *Gangamopteris* and *Glossopteris* floras. I believe that Dr P.R. Evans has isolated spores from horizons which contain 'Lower Bowen type' *Noeggerathiopsis*, and it will be interesting to see whether the separation of Upper and Lower Permian on this basis is valid. If it is, I think the time has come to give a new name to the leaves involved - a new genus 'of unknown affinities' would be far less confusing to deal with. *Noeggerathiopsis hislopi* could then be more closely defined and limited.

The range of the limited *Noeggerathiopsis hislopi*, with leaves narrow in proportion to their length, veins parallel, and tapering gradually to a relatively broad base (many examples are known where such leaves are found attached in radiate manner) is Permian to Lower Triassic. But the range of the new genus would be Lower Permian and Upper Carboniferous.

# APPENDIX 3

## CARBONIFEROUS FOSSILS FROM THE DUARINGA SHEET AREA

by

J.F. Dear

(Queensland Geological Survey)

Locality DU131/4, in gully on western bank of the Fitzroy River 2 miles W of Armagh homestead (280098).

Determinations : Schizophoria cf. resupinata (Martin), Rhipidomella sp. ind., Productina sp., Chonetipustula sp., Plicochonetes sp., Prospira sp. ind., Cleiothyridina sp. ind., Crurithyris sp., Straparollus sp., Indet. solitary coral.
Age: Upper Tournaisian

Locality DU365, 3.5 miles SSE of Armagh homestead (286093).

Determinations : Levipustula levis Maxwell, Neospirifer sp., Composita sp., Indet. orthotetid, Rhombopora sp., Fenestella rectangularis (Crockford), Polypora sp. ind., Indet. dielasmatid.
Age: Upper Carboniferous

Locality DU598, 2 miles SSW of Armagh homestead (282094).

Determinations : Spinuliplica cf. spinulosa Campbell, Liriplica sp. ind., Composita sp., Lisella sp., Indet. dielasmatid, cf. Sanguinolites sp., Conocardium sp., Polypora tenuirama Crockford, Fenestella sp. ind.
Age: Upper Carboniferous

Locality DU943, along track, 2 miles W of Craigilee homestead (281102).

Determinations : Levipustula levis Maxwell, Spinuliplica sp. ind., Composita sp., ?Conocardium sp., Fenestella cincta (Crockford), Fenestella cf. cerva Campbell, Fenestella malchi (Crockford), Fenestella micropora (Crockford), Polypora sp. ind.
Age: Upper Carboniferous

Locality DU949, 2 miles W of Craigilee homestead (280101).

Determinations : Spinuliplica sp. ind.
Age: Upper Carboniferous

Locality DU1201, 2 miles NE of Armagh homestead (286100).

Determinations : Streptorhynchus sp., Reticulatia sp., Phricydothyris sp., Punctospirifer sp., Rhombopora sp., cf. Evactinopora sp.
Age: Upper Carboniferous

Locality DU1202, 2 miles NE of Armagh homestead (286100).

Determinations : Levipustula levis Maxwell, Alispirifer cf. laminosus Campbell, Neospirifer pristinus Maxwell, Peruvispira sp., Indet. pectinoid pelecypod, Rhombopora sp.
Age: Upper Carboniferous.

Remarks:

The assemblage from DU131/4 is considered to be of probable Upper Tournaisian age. Productina sp. compares closely with that figured by Maxwell (1954, pl. 3, figs 9a,b) as Productus cf. minutus Muir-Wood from the Upper Tournaisian Schizophoria Zone of the Mount Morgan district. A similar species was described by McKellar (1961, pl. 1, figs 5-8) from the Upper Tournaisian of the Bancroft district, to the northeast of Monto. Productina is unknown in the Visean faunas of the Yarrol Basin. A species of Plicochonetes almost identical with Plicochonetes sp. occurs in Upper Tournaisian strata at Cania, to the northwest of Monto. Schizophoria cf. resupinata ranges through most of the Tournaisian and Visean of the Yarrol Basin, and none of the remaining species from collection DU131/4 are of value in age determination.

The most abundant form in collection DU1201 is Streptorhynchus sp. This genus has not been recorded previously from the Carboniferous of Queensland but occurs in the Upper Carboniferous of New South Wales (Campbell, 1962). The presence of Reticulatia sp., Phricydothyris sp., and cf. Evactinopora sp. in this assemblage suggests correlation with the faunas of the Branch Creek Formation of the Yarrol district (Maxwell, 1960). Fleming (1960) considered that the bryozoa from the Branch Creek Formation closely resembled those found in the basal portion of the Neerkol Beds in the Stanwell district.

Most of the bryozoa found in the assemblages DU365, DU598, and DU943 are characteristic of the Neerkol Beds; the presence in these assemblages of Levipustula levis and Spinuliplica cf. spinulosus strengthens the correlation with the fauna of the Neerkol Beds. Neospirifer pristinus from collection DU1202 compares closely with the type material figured by Maxwell (1951, pl. 3, figs 1-8) from the Neerkol Beds.

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## APPENDIX 4

## FOSSIL CORALS COLLECTED IN THE DUARINGA SHEET, 1962.

by

Dorothy Hill

DU 600F: Limestone near Armagh homestead.

Heliolites daintreei, first group, Favosites sp. cf. goldfussi, F. sp., Tryplasma sp., ?Fletcheria sp. or ?Fletcherina sp.

Stromatoporoid

Algae

Age: Silurian or Lower Devonian. The fauna is of long-ranging types. H. daintreei ranges from Middle Silurian to Lower Middle Devonian. The large-celled Favosites is perhaps closer to the Lower and Middle Devonian F. goldfussi than to the Silurian and Lower Devonian F. gotlandica. The solitary Tryplasma indicates Silurian or Lower Devonian. The cylindrical fragments called ?Fletcheria or ?Fletcherina are probably from a fasciculate corallum, but having very negative characters such as extremely short septa they are difficult to place generically. The type species of Fletcheria is Silurian and that of Fletcherina is Devonian. On the whole I incline to a Lower Devonian age, but the possibility of a Silurian age cannot be discarded.

DU 948: Grey limestone 2 miles NW of Craigilee homestead.

Lithostrotion ex.gr. stanvellense Etheridge

Age: Lower Carboniferous, probably Visean.

DU 599: Near Armagh homestead.

Lithostrotion arundineum Eth., Syringopora, 2 species.

Age: Lower Carboniferous, probably Visean.

DU 160: Grey limestone near west bank of Fitzroy River, near Craigilee weir-crossing.

Lithostrotion columnare Etheridge, Symplectophyllum sp.

DU 146: Near Thuriba homestead. The limestone is very sheared and determination is hazardous. The following were identified:

Alveolites? three fragments; Tryplasma? pieces of corallites from a cylindrical corallum; Cladochonus? pieces of corallites; Favosites sp. (very small fragment); Coroid rugose coral, indet.; Solitary zaphrentoid Rugosa, gen. et sp. indet. Small sparse fragments of branching Polyzoa.

As the first two genera mentioned are not known from rocks younger than the Devonian, and as both are common to Silurian and Devonian, I regard the age of the limestone as possibly Silurian or Devonian.

However, owing to the degree of recrystallization, a safer determination of age would be Palaeozoic (Ordovician to Permian).

## APPENDIX 5

## FOSSILS FROM LONG, BARREN, AND HUNTER ISLANDS, QUEENSLAND

by

John Roberts

(1) Long and Barren Islands

Identifications.

Long Island South (275233, Saint Lawrence Sheet).

Locality 1* *Syringopora* sp.
Locality 2 *Cyrtospirifer?* sp.
Locality 3 *Cyrtospirifer?* sp.
Locality 4 *Cyrtospirifer?* sp.

Long Island North Point (276248, Saint Lawrence Sheet).

Locality 5 *Fenestella* sp. indet.

Locality 6 *Levipustula levis* Maxwell, 1951, *Spinuliplica spinulosa* Campbell, 1961, *Composita* cf. *magnicarina* Campbell, 1961, *Schuchertella* sp., *Fenestella* cf. *micropora* Crockford, 1948., *Fenestella* sp. indet., *Rhombopora? bifurcata* Campbell, 1961., *Fistulamina dispersa* Crockford, 1948.

Locality 7 *Levipustula levis* Maxwell, 1951

Barren Island, southern coast. Lat. 22°02'S. long. 149°58½'E. Port Clinton Sheet.

Locality 8 *Levipustula levis* Maxwell, 1951.
Locality 9 *Levipustula levis* Maxwell, 1951, *Composita* sp., *Fenestella* sp. indet.

*Cyrtospirifer?* sp. suggests an Upper Devonian age for beds in the southern portion of Long Island, but because the specimen could not be positively identified they could be younger. *Cyrtospirifer?* sp. possesses a radial ornament and long cardinal area typical of *Cyrtospirifer* sensu stricto. The dental lamellae in the pedicle valve are shorter than in most species of this genus, but forms with dental lamellae of comparable length have been described from the Upper Devonian of Belgium (*C. grabaui* Paeckelman by Vandercammen, 1959) and USA (*C. oleanensis* Greiner, 1957). Large and presumably older examples of these overseas species have very reduced dental lamellae similar to those in the Queensland specimens. The relative coarseness of the denticle grooves on the cardinal area suggests that this form could be closer to the Lower Carboniferous genus *Unispirifer*. The latter form, however, is readily distinguished by its coarser external ornament, shorter cardinal area on the pedicle valve, and much smaller size.

The presence of *Levipustula levis* Maxwell, *Spinuliplica spinulosa* Campbell, *Composita* cf. *magnicarina* Campbell, *Fenestella* cf. *micropora* Crockford, and *Fistulamina dispersa* Crockford in the Long Island North Point fauna indicates that it is of Middle Carboniferous (Moscovian) age.

(2) Hunter Island is located in the Duke Group of islands, east of Mackay, and north of the Port Clinton Sheet area. East coast approximately 1 mile from Southern Point. Lat. 21°58'S., long. 150°08½'E.

Identifications

Locality 10 *Favosites* sp.
Solitary rugose coral
Locality 11 *Heliolites* cf. *daintreei* Nicholson & Etheridge, 1879.

?*Gephuropora duni* Etheridge, 1920.
Solitary zaphrentoid rugose coral.

Locality 12 *Favosites* sp.
Locality 13 *Favosites* sp.
Locality 14 Goniatite gen. and sp. indet.

The age of the Hunter Island faunas, with the possible exception of locality 14, is Middle Devonian or older. If the determination of *Gephuropora duni* Etheridge is correct, the faunas can be more precisely dated as lower Middle Devonian. However, extensive recrystallization of the limestone on Hunter Island has hampered identification of genera and species.

The external ornament on the specimen from locality 14 somewhat resembles that found on a number of clymenid goniatites, but because sutures have not been found it is problematical whether this form can be referred to a genus in the Suborder Clymeniina. If further material proves this specimen to be a clymenid form, the beds at locality 14 are younger than those at the other localities, i.e. Upper Devonian.

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## APPENDIX 6

## PLANT FOSSILS FROM BURNGROVE CREEK, DUARINGA SHEET AREA.

by

J.T. Woods and J.F. Dear

(Queensland Geological Survey)

Locality : Burngrove Creek, about 1/4 mile below junction with Cabbage Tree Creek, Blackwater district.

Collectors : H.G.S. Cribb and W.L. Hawthorne; September, 1962.

Determinations : Sphenopteris lobifolia Morris, Glossopteris angustifolia Brongniart, G. indica Schimper, G. browniana Brongniart, G. conspicua Feistmantel, Glossopteris scale leaves, Fructification cf. Ottokaria sp.

Age: Upper Permian

Plant impressions are abundant and well preserved in cherty siltstone, but comparatively few species are represented. Most of the glossopterid species are widely ranging; the exception is Glossopteris conspicua, which is restricted to the Upper Bowen Coal Measures and their equivalents in eastern Australia.

Walkom (1922) recorded, as Glossopteris sp., a fragmentary specimen from the Ballast Quarry, Burngrove Creek. It appears to be referable to G. browniana.

The unattached fructification compared with Ottokaria differs from typical representatives of the genus, as figured by Plumstead (1956), in having the 'head' fan-shaped rather than orbicular, the depressions for 'seed-bodies' much fewer, and the 'bracts' restricted to a crown of five instead of being disposed around the periphery. Plumstead associated Ottakaria with Gangamopteris.

The fronds identified as Sphenopteris lobifolia form the most common element of the collection. They show considerable variation in the size, shape, venation, and degree of location of the ultimate pinnules, and comparison with material identified by Walkom (1922) as S. lobifolia, S. polymorpha, and Cladophlebis roylei suggests that much of this is conspecific.

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## APPENDIX 7

## UPPER SILURIAN MARINE FOSSILS FROM ARMAGH HOMESTEAD, DUARINGA SHEET AREA

by

R.G. McKellar

Locality : 1/4 mile northeast of Armagh homestead (28450985).

Collection CU 228A : in grey limestone. Tryplasma sp., Favosites aff. allani Jones, Plasmopora sp., Coenites sp.

Age: Upper Silurian.

Remarks:

A small coral fauna including Heliolites daintreei, Favosites cf. goldfussi, Favosites sp., Tryplasma sp., and (?) Fletcheria sp. or (?) Fletcherina sp. was identified from this unit by Hill (Collection DU 600, App. 4, this Report). In the present collection, from a locality east of Du 600, corals appear.

Tryplasma sp. has small corallites of 3.5-5.0 mm diameter, with approximately 25 acanthine septa of each order, and variably spaced, almost flat tabulae. It is similar to the fragment identified as Tryplasma sp. from the Lower Devonian Mount Etna Limestone by Hill (1942), but the species from Lower or Middle Devonian limestone of the Riverston Beds on the Monto Sheet (McKellar, 1964) has considerably larger corallites (7-10 mm) and the tabulae usually sag deeply.

Favosites aff. allani Jones has small polygonal corallites 1.2-1.4 mm in diameter, with relatively unthickened walls. Septal spines are fairly numerous and short; tabulae are closely spaced (10-15 in 5 mm), but become more crowded distally; mural pores occur in a single median series on a corallite face. The species occurs in Upper Silurian strata in eastern Australia. Plasmopora sp. has a somewhat thickened corallum with twelve tubuli typically surrounding each of the tabularia. There are twelve long, wholly acanthine septa in tabularia, and this has importance, as only species of Wenlockian and Ludlovian age (Silurian) have such septa. Other Australian species have either no septal spines, or simple rudimentary knob-like swellings of the walls.

Professor Hill was able to suggest an Upper Silurian or Lower Devonian age for her material; however, with this new collection, particularly the species of Plasmopora, I think this can now be safely refined to the Upper Silurian.

Collection Du 228B : in red-brown, fine calcareous sandstone. Indet. (?) pentameroid brachiopod, Stropheodontidae indet., Camarotoechia sp. or Stegerhynchus sp., (?) Atrypacea indet., Encrinurus cf. mitchelli Foerste.

Age: Upper Silurian.

Remarks:

Camarotoechia sp. or Stegerhynchus sp. has a single plication in the sulcus of the pedicle valve, and an indefinite fold with two plications on the brachial valve. Internally, the pedicle valve has short fine dental lamellae, and in the brachial valve, small plates unite inner margins of the hinge plates with the median septum and form a short cruralium. A cardinal process does not appear to be developed. The species is extremely similar to material in the Geological Survey from the Melbourne area, but locality information is too imprecise for it to help in correlation. Stegerhynchus was listed by Talent (1965) from the McIvor Formation of late Silurian to early Devonian age in the Heathcote-Redcastle area in Victoria.

Two trilobite pygidia which appear to be identical with that of Encrinurus mitchelli Foerste from the lower trilobite bed of the Bowning Series, New South Wales, occur in the collection. These beds are regarded as Upper Silurian. In Victoria Encrinurus occurs in the upper part of the Dargile Formation (Ludlovian) in the Heathcote area. Genera of the family Encrinuridae are not known in strata younger than the Silurian. Thus I have no hesitation in assigning an Upper Silurian age to this fauna.

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PLATE 1

Fig. 1 : Rannes Beds, recumbent folds Gogango Range, road cutting 3.75 miles west of Grantleigh Siding.

Fig. 2 : Rannes Beds, Small thrust, road cutting Gogango Range, 5 miles west of Grantleigh Siding.

PLATE 2

Fig. 1 : Rookwood Volcanics, silicified pillow lavas 3 miles north-north-west of Rookwood Homestead.

Fig. 2 : German Creek Coal Measures, Coal Seam in German Creek, Saint Lawrence Sheet area.

PLATE 3

Fig. 1 : Boomer Formation, interbedded mudstone and White sandstone showing relation of cleavage to bedding.

Fig. 2 : Boomer Formation, typical folding of interbedded sandstone-siltstone sequence in dominantly sandstone facies. Note right-angled trough and compressed siltstone/claystone interbeds. Fitzroy River, Riverslea Homestead.

PLATE 4

Fig. 1 : Blackwater Group, fossil wood in Bundaleer Homestead area.
Note slight depression of bedding below wood.

Fig. 2 : Burngrove Formation, animal tracks on the surface of a siltstone bed, 6 miles north of Cooroorah Homestead.

PLATE 5

Fig. 1 : Burngrove Formation, animal tracks on the surface of a siltstone bed, 6 miles north of Cooroorah Homestead.

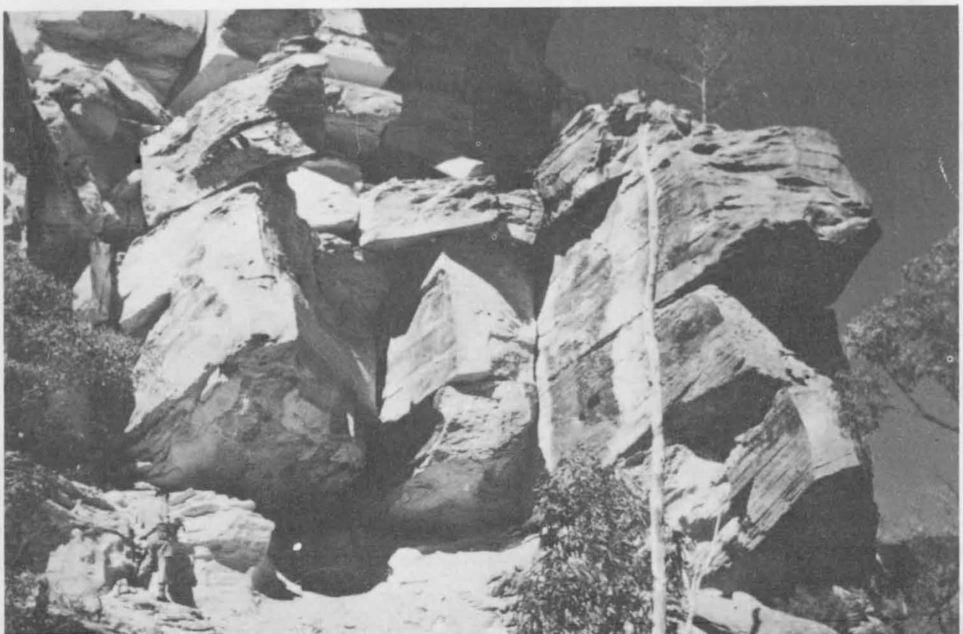


Fig. 2 : Precipice Sandstone Cliff, east of Yarrawonga Homestead, Duaringa Sheet area.

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

# DUARINGA
QUEENSLAND

SHEET SF 55-16

PRELIMINARY EDITION, 1965

SUBJECT TO AMENDMENT

PLATE 6



## Reference

- Geological boundary
- Anticline
- Syncline
- Monocline
- Overturned anticline
- Overturned syncline
- Minor fold, showing plunge
- fault (D, U indicate relative movement down, up)

*Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes*

- Strike and dip of strata
- Horizontal strata
- Vertical strata
- Unmeasured dip
- Overturned strata
- Dip <15° (air-photo interpretation)
- Dip 15-45° (air-photo interpretation)
- Trend lines (air-photo interpretation)
- Joint pattern (air-photo interpretation)
- Strike and dip of foliation
- Vertical foliation

- U.D.C.2 Macrofossil locality
- 775 Plant fossil locality
- Fossil wood locality
- Sample locality for age determination
- Dyke

- Dry oil well - abandoned
- Mine, not being worked
- Quarry
- Prospect
- Au Gold
- C Coal
- Rm Road metal

- Road
- Vehicle track
- Railway with station, siding
- "Leura" HS Homestead
- Building
- Yd Yard
- Landing ground

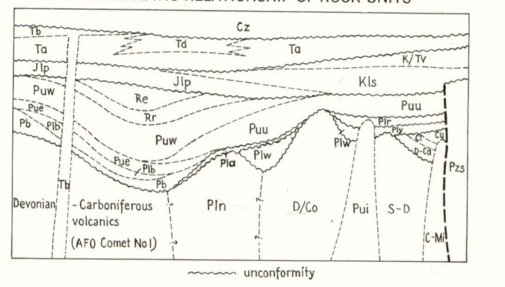
- E Earth tank
- Earth dam
- Water bore
- WH Waterhole
- Waterhole in stream

- Cliff
- 282' Height in feet, approximate; datum: mean sea level

## Reference

| | | | | |
|---|---|---|---|---|
| CAINOZOIC | QUATERNARY | | Qa | Alluvial sand, silt and gravel |
| | UNDIFFERENTIATED | | Cz | Sand, soil, gravel, ferruginous gravel and reworked laterite |
| | | | Czp | Piedmont deposits |
| | TERTIARY | | (laterite pattern) | Laterite |
| | | | Ta | Sandstone, siltstone, claystone, quartz pebble and fine conglomerate, diatomite, oil shale. Minor basalt |
| | | | Td | Sandstone breccia |
| | | | Tb | Basalt flows; rare plugs and sills |
| MESOZOIC | CRETACEOUS - TERTIARY | | K/Tv | Mainly trachytic flows, pyroclastics, stocks and dykes |
| | LOWER CRETACEOUS | Styx Coal Measures | Kls | Conglomerate, sandstone, siltstone |
| | LOWER JURASSIC | Precipice Sandstone | Jlp | Quartz sandstone, cross-bedded, pebbly |
| | TRIASSIC | Mimosa Group: Clematis Sandstone | Re | Quartz sandstone, cross-bedded, medium to coarse grained; some siltstone interbeds |
| | | Mimosa Group: Rewan Formation | Rr | Red, buff, and grey-green mudstone, with interbeds of green lithic sandstone |
| | | Mimosa Group: Sagittarius Sandstone Member | Rs | Green feldspathic and lithic sandstone with red and green mudstone interbeds |
| PALAEOZOIC | PERMIAN - MESOZOIC | | P-Mi | Granite, granodiorite, diorite, gabbro |
| | CARBONIFEROUS - MESOZOIC | | C-Mi | Adamellite |
| | UPPER PERMIAN | | Pui | Adamellite |
| | | Blackwater Group: Undifferentiated | Puw | Lithic and feldspathic sandstone, calcareous in places, siltstone, mudstone, carbonaceous mudstone, coal, limestone, tuff, white and green ashstone with abundant plant fossils |
| | | Blackwater Group: Rangal Coal Measures | Puj | Carbonaceous mudstone, coal, siltstone, feldspathic and lithic sandstone, calcareous in places, white ashstone |
| | | Blackwater Group: Burngrove Formation | Pug | Green ashstone and siliceous siltstone, dark carbonaceous mudstone, thinly interbedded mudstone and fine lithic sandstone, calcareous lithic and feldspathic sandstone |
| | | Blackwater Group: Fair Hill Formation | Puh | Labile sandstone, calcareous in places with horizons of discoidal calcareous concretions, tuffaceous sandstone and conglomerate, mudstone |
| | | Back Creek Group: Boomer Formation | Puu | Volcanic sandstone, blue siltstone, dark carbonaceous mudstone, interbedded in places, conglomerate |
| | | Back Creek Group, Blenheim Sub-group: Undifferentiated | Pue | Quartz sandstone, sub-labile sandstone, blue micaceous siltstone, mudstone, calcareous sandstone and sandy coquinite, conglomerate |
| | | Back Creek Group, Blenheim Sub-group: German Creek Coal Measures | Pud | Quartz sandstone; Sub-labile sandstone, micaceous siltstone, carbonaceous siltstone and mudstone, coal, conglomerate |
| | | Back Creek Group, Blenheim Sub-group: Maria Formation | Pum | Micaceous siltstone, mudstone, calcareous sub-labile sandstone |
| | | Back Creek Group, Blenheim Sub-group: Oxtrack Formation | Puo | Limestone, calcilutite, siltstone, calcareous sandstone |
| | LOWER PERMIAN | Back Creek Group: Gebbie Sub-group | Plb | Sub-labile sandstone, quartz sandstone, blue-grey micaceous siltstone, nodular in places; interbedded siltstone and silty sandstone; calcareous sandstone lenses |
| | | Back Creek Group: Undifferentiated | Pb | Volcanic sandstone, pebbly, calcareous and fossiliferous in places, limestone, coquinite, mudstone, micaceous siltstone, tuff, acid to intermediate flows; phyllite and sheared siltstone |
| | | Carmila Beds | Pla | Acid to intermediate volcanics, conglomerate, sandstone, siltstone, calcareous tuff, limestone |
| | | Rookwood Volcanics | Plr | Spilitic pillow lavas, agglomerate, breccia, trachyte, keratophyre, chert |
| | | Youlambie Conglomerate | Ply | Conglomerate, siltstone, massive and banded chert |
| | LOWER PERMIAN AND OLDER? | Rannes Beds | Plw | Mudstone, siltstone, greywacke, conglomerate, limestone, tuff, agglomerate, trachyte, phyllite; Acid to intermediate volcanics and volcanic conglomerate |
| | | Camboon Andesite(?) | Pln | Andesitic, dacitic, and basaltic tuff, agglomerate and flows; volcanic conglomerate and sandstone |
| | UPPER CARBONIFEROUS | Yarrol Basin Sequence: Neerkol Formation | Cu | Calcareous siltstone and sandstone, bryozoan mudstone, conglomerate, sandy coquinite, dark siliceous siltstone |
| | LOWER CARBONIFEROUS | Yarrol Basin Sequence | Cl | Oolitic limestone, silicified in part, chert, sub-labile sandstone, siltstone |
| | DEVONIAN - CARBONIFEROUS | Yarrol Basin Sequence | D-Ca | Oolitic limestone, chert, siliceous siltstone, calcareous siltstone and sandstone, mudstone, conglomerate |
| | | Connors Volcanics | D/Co | Rhyolitic, dacitic, trachytic and andesitic volcanics, tuffaceous sediments and volcanic conglomerate, silicified, jointed and quartz veined |
| | SILURIAN - LOWER DEVONIAN | | S-D | Spilite, keratophyre, altered trachyte flows, volcanic conglomerate, agglomerate, tuff, chert, fossiliferous limestone and marble |
| | LOWER? PALAEOZOIC | | Pzs | Serpentinite |

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



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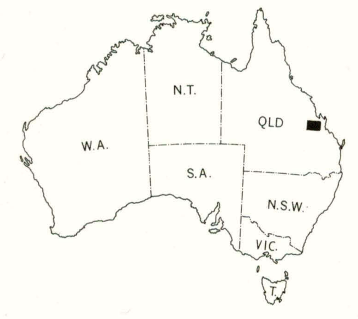
Transverse Mercator Projection.



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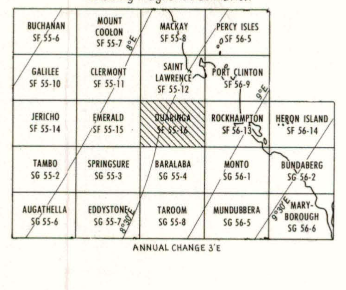

Scale 1:250,000

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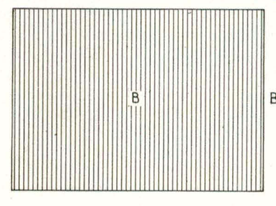
5 0 5 10 15 20 25 KILOMETRES



GEOLOGICAL RELIABILITY DIAGRAM

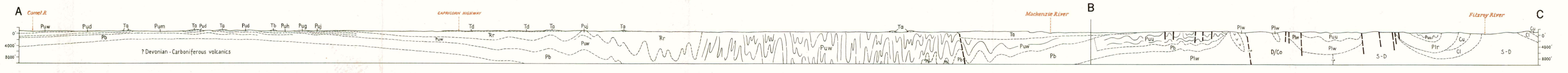


B Semi-detailed mapping, numerous traverses

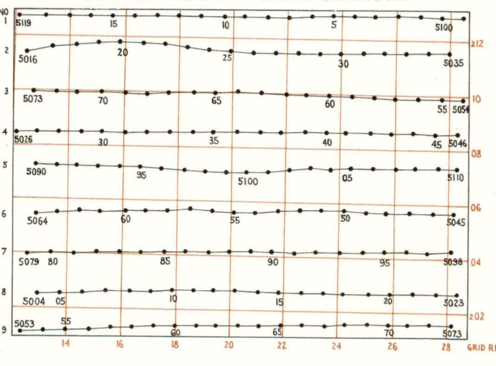
Geology, to 1965, by: E.J. Malone, F. Olgers, A.G. Kirkegaard (G.S.Q.), R.G. Mollan, A.R. Jensen; D. King, P. Goscombe, L. Hansen (Utah Development Co.); and S.S. Derrington, K.H. Morgan (Mines Administration Pty. Ltd.)
Compiled, 1965, by: F. Olgers, E.J. Malone, A.G. Kirkegaard
Drawn by: E.H.J. Feeken

Section

Folding partly diagrammatic
(Qa and Cz omitted)
Scale $\frac{V}{H} = 1$



AIR PHOTOGRAPH FLIGHT DIAGRAM



AUSTRALIA 1:250,000

# ST LAWRENCE
QUEENSLAND

1:250,000 GEOLOGICAL SERIES SHEET SF 55-12

PRELIMINARY EDITION, 1967

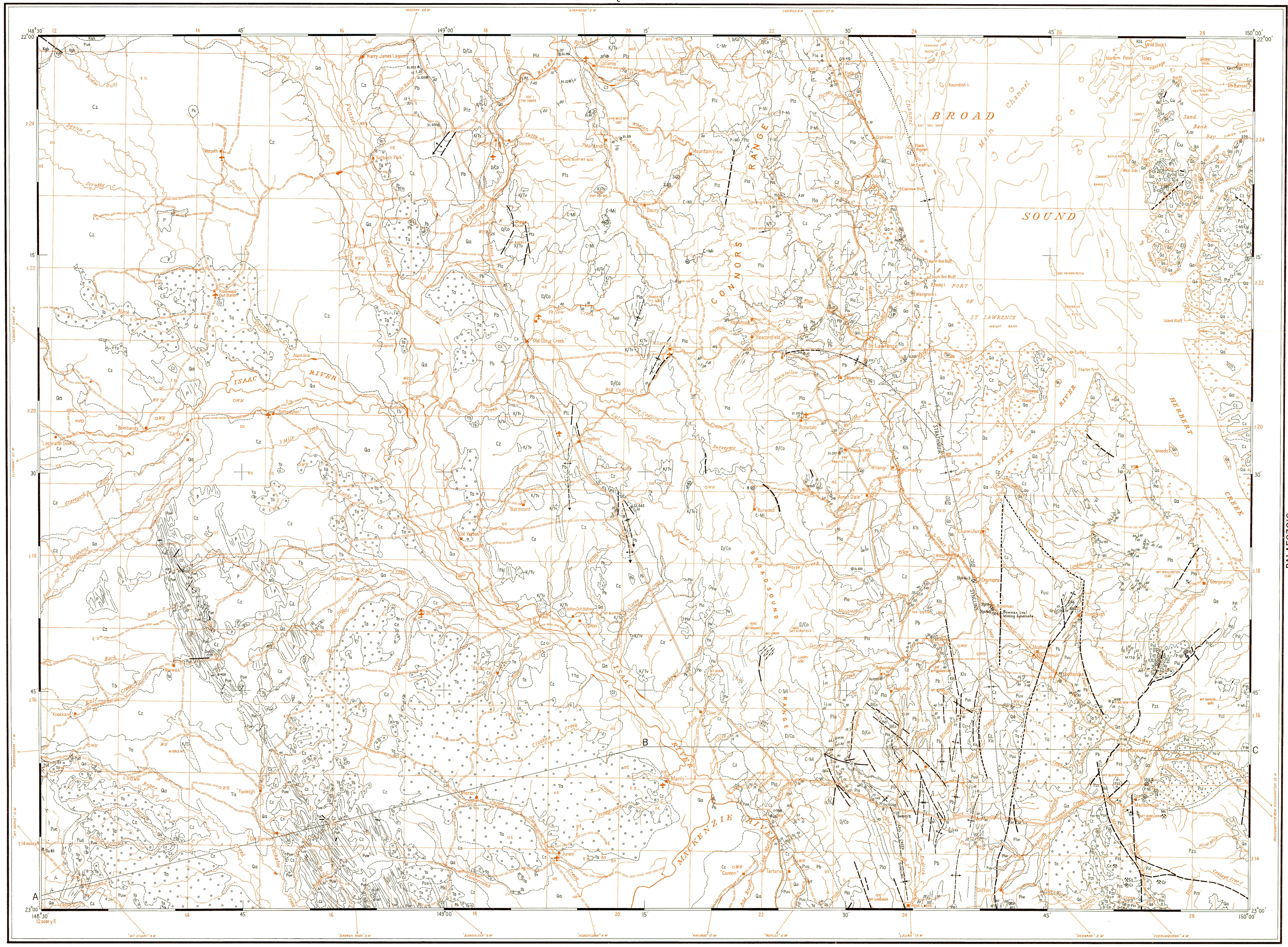
SUBJECT TO AMENDMENT



PLATE 7

## Reference

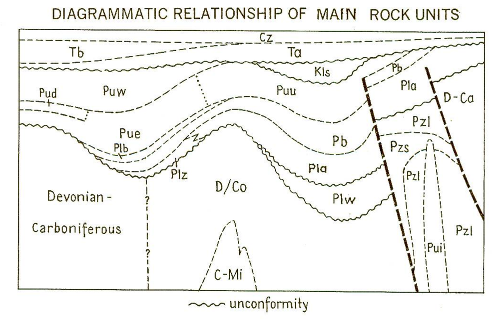
- Geological boundary
- Anticline, showing direction of plunge
- Syncline
- Fault
- Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes
- 25 Strike and dip of strata
- Horizontal strata
- Vertical strata
- Unmeasured dip
- Dip < 15° } air-photo interpretation
- Trend lines } air-photo interpretation
- Joint pattern } air-photo interpretation
- 70 Strike and dip of foliation
- Vertical foliation
- Macrofossil locality
- Plant fossil locality
- Fossil wood
- M 72 Text reference to fossil locality
- 15 Age determination sample (reference number prefixed by F55/12)
- Dyke; tr - trachyte
- Mine
- Mine, not worked
- Au Gold
- C Coal
- Cr Chromium
- Cs Chrysoprase
- Ms Magnesite
- Water bore
- E Earth tank
- Earth dam
- WH Waterhole
- Waterhole in stream
- Windpump
- Swamp
- Mangroves
- Reef
- 6 Fathom line
- Road
- Vehicle track
- Railway with station, siding
- "Rosedale" Homestead
- Building
- Landing ground
- Yd Yard
- 1410′ Spot elevation, approximate; datum: mean sea level




## Reference

| | | | | |
| --- | --- | --- | --- | --- |
| CAINOZOIC | UNDIFFERENTIATED | | Cz | Sand, soil, alluvium, lateritic gravel and soil |
| | QUATERNARY | | Qa | Alluvium, coastal swamp deposits |
| | TERTIARY | | | Laterite and reworked laterite |
| | | | Ta | Sandstone, siltstone, claystone, diatomite, conglomerate, some volcanics |
| | | | Tb | Basalt |
| MESOZOIC | CRETACEOUS - TERTIARY | | K/Tt | Trachy-syenite plug, intermediate plug and dykes |
| | | | K/Tv | Rhyolitic, dacitic and andesitic lavas and pyroclastics, and some plugs and dykes |
| | LOWER CRETACEOUS | Bundarra Granodiorite | Kgb | Leuco granodiorite, alkali granite tending to syenite |
| | | Styx Coal Measures | Kls | Quartz sandstone, conglomerate, siltstone, carbonaceous shale, coal |
| | PERMIAN - MESOZOIC | | P-Mi | Granodiorite, monzonite, granite, micro-granite, gabbro |
| | CARBONIFEROUS - MESOZOIC | | C-Mi | Granite, granodiorite, adamellite diorite, gabbro; trachyte dykes |
| | | Urannah Complex | C-Mr | Granite, adamellite, tonalite, micro-granite, micro-diorite, andesite and dacite dykes |
| PALAEOZOIC | UPPER PERMIAN | | Pui | Hornblende biotite adamellite, granite, granodiorite |
| | | | | Diorite |
| | | | | Gabbro |
| | | | | Granite |
| | | Blackwater Group | Puw | Lithic and feldspathic sandstone, calcareous in places, siltstone, carbonaceous shale, coal, green siliceous siltstone with plant remains, volcanic sandstone and conglomerate |
| | | Blackwater Group and Blenheim Sub-group | P | Siltstone, sub-labile sandstone |
| | LOWER - UPPER PERMIAN | Back Creek Group: Undifferentiated | Pb | Volcanic, feldspathic and lithic sandstone, sub-labile sandstone, siltstone, nodular, calcareous, micaceous and pebbly in places, pebbly volcanic sandstone, limestone, calcareous lithic sandstone, minor crystal, lithic and vitric tuffs, sheared siltstone, phyllite |
| | | Boomer Formation | Puu | Siltstone, claystone, volcanic sandstone, thinly to thickly interbedded in most places, siltstone and carbonaceous claystone closely interbedded, pebble and cobble conglomerate, lithic-feldspathic greywacke |
| | | Blenheim Sub-group | Pue | Blue-grey siltstone, micaceous, carbonaceous, worm-tracked in places, quartzose and sub-labile sandstone, calcareous sandstone and sandy limestone, quartz pebble conglomerate; contact metamorphosed sediments in north-west |
| | | German Creek Coal Measures | Pud | Quartz sandstone, sub-labile sandstone, micaceous and carbonaceous siltstone, carbonaceous shale, coal, quartz pebble conglomerate |
| | | Gebbie Sub-group | Plb | Sub-labile sandstone, calcareous in places, lenses and beds of hard calcareous sandstone and sandy limestone, siltstone, grey, blue, micaceous, and containing hard round nodules in places |
| | LOWER PERMIAN | Carmila Beds | Plo | Conglomerate, tuffaceous conglomerate, siltstone, mudstone, carbonaceous shale, coal, lithic and volcanic sandstone; rhyolite, dacite, trachyte and andesite flows and pyroclastics; fossiliferous, calcareous tuffs and tuffaceous sandstone and limestone |
| | | Lizzie Creek Volcanics | Plz | Andesite, trachyte, dacite and basalt flows and pyroclastics; volcanic derived sediments including volcanic sandstone and conglomerate, interbedded dark siltstone, tuffaceous sandstone and tuff, fossiliferous calcareous tuff and tuffaceous sandstone, bioclastic limestone |
| | | Rannes Beds | Plw | Sheared siltstone, phyllite, tuffaceous and lithic sandstone |
| | | | Pl | Siltstone with ferruginous concretions, feldspathic sandstone, lithic conglomerate |
| | UPPER CARBONIFEROUS | Yarrol Basin Sequence | Cu | Calcareous siltstone, bryozoan mudstone, sandstone, calcareous sandstone, conglomerate |
| | LOWER CARBONIFEROUS | | Cl | Oolitic limestone, sandstone, siltstone |
| | DEVONIAN - CARBONIFEROUS | | D-Ca | Limestone, siltstone, sandstone, conglomerate, mudstone, tuff and tuffaceous sandstone |
| | | Connors Volcanics | D/Co | Rhyolite, dacite, trachyte and andesite flows, auto-breccia, and agglomerate and minor tuff, tuffaceous sediments and volcanic conglomerate; extensively silicified, jointed, quartz veined |
| | ? LOWER PALAEOZOIC | | Pzs | Serpentinite |
| | | | Pzl | Quartz mica schist, quartzite, talc schist, hornfelsed quartz mica schist, pyroxenite |

DIAGRAMMATIC RELATIONSHIP OF MAIN ROCK UNITS

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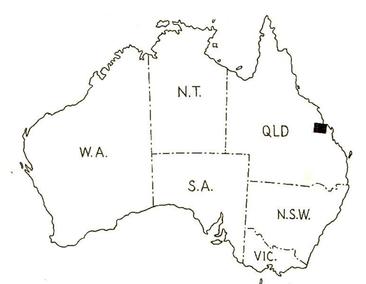


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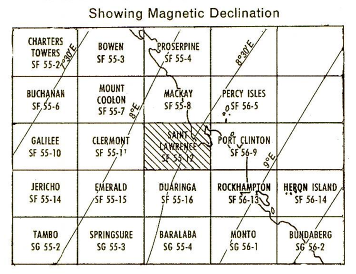


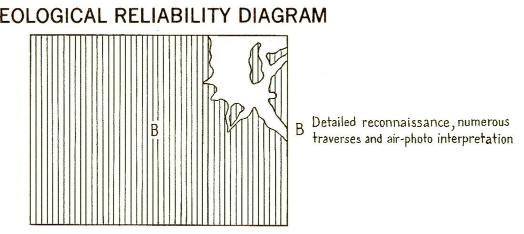

Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES



GEOLOGICAL RELIABILITY DIAGRAM




Geology to 1964 by: E.J. Malone, F. Olgers, A.R. Jensen, R.G. Mollan, and C.M. Gregory (B.M.R.); A.G. Kirkegaard and V.R. Forbes (G.S.Q)
Compiled, 1965, by: E.J. Malone, F. Olgers, A.G. Kirkegaard
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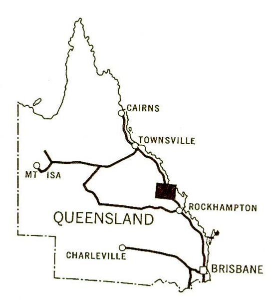
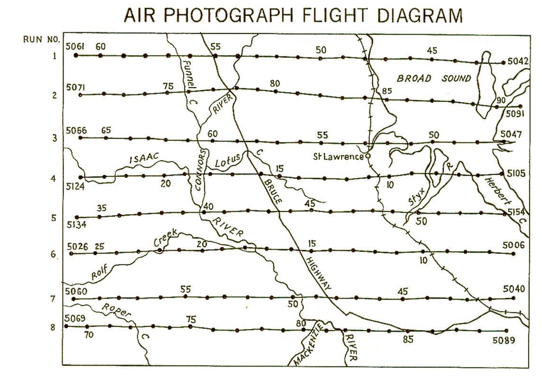



AIR PHOTOGRAPH FLIGHT DIAGRAM

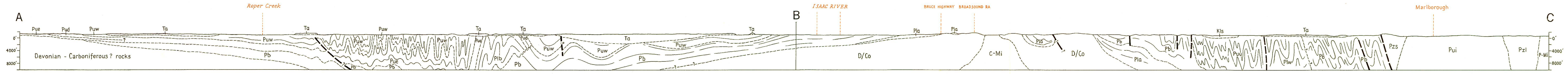


## Section

Folding partly diagrammatic

(Qa and Cz omitted)

Scale: V/H = 1

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