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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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SUMMARY

The geology of the Eddystone and Taroom 1:250,000 Sheet areas and the western part of the Mundubbera 1:250,000 Sheet area was mapped in 1963 and 1964 jointly by the Bureau of Mineral Resources and Geological Survey of Queensland. The area is about 500 km northwest of Brisbane and covers the southern end of the exposed part of the Bowen Basin and part of the eastern margin of the Great Artesian Basin.

Pre-Permian rocks are exposed in the Auburn Complex in the east, and in a small inlier of Lower Palaeozoic(?) gabbro in the west, which forms part of the Nebine Ridge.

Permian sequences crop out in two widely separated areas. Most of the sequence in the east was deposited in an Upper Permian depression known as the Mimosa Trough, whereas much of the sequence in the Serocold Anticline in the west was deposited in the Lower Permian Denison Trough. The Upper Permian sequence extends westwards at least as far as the Nebine Ridge and is underlain by the Lower Permian Camboon Andesite in the Mimosa Syncline and possibly as far west as the Morella Anticline.

The Permian sequence in the eastern limb of the Mimosa Syncline consists of a basal volcanic unit (Camboon Andesite), 200 m of Lower Permian marine limestone and clastics (Buffel Formation), and about 2250 m of Upper Permian marine sediments (Oxtrack, Barfield, and Flat Top Formations) and non-marine sediments (Gyranda Formation and Baralaba Coal Measures). The Buffel Formation probably rests disconformably on the Camboon Andesite. The Camboon Andesite, which includes volcanics originally named the Cracow Volcanics, is intruded by the Auburn Complex, though parts of the complex are probably older than the Camboon Andesite.

The sequence in the Serocold Anticline consists of at least 3600 m of Lower Permian marine and non-marine sediments (Reids Dome Beds, Cattle Creek Formation, Black Alley Shale, and Blackwater Group). Only the uppermost part of the Lower Permian sequence is exposed. The Peawaddy Formation rests unconformably on older formations southwards.

The Upper Permian sequence in both east and west is overlain by non-marine Triassic sediments. The oldest Triassic unit is a redbed sequence (Rewan Formation), which ranges from about 600 m thick west of the Mimosa Syncline to about 3600 m in the east. It is overlain by fluviatile quartzose sandstone (Clematis Sandstone), 120 m thick in the west and 300 m in the east. The Clematis Sandstone is conformably overlain by a Middle to Upper Triassic sequence of labile sandstone and lutite (Moolayember Formation), which is 300 m thick in the west and 1350 m in the east.

The Permo-Triassic rocks have been folded in the west into a broad anticlinorium which includes several domes, and is bounded on the west by the Merivale Fault. The sequence probably thins west of the fault and onlaps the Nebine Ridge. The Mimosa Syncline is asymmetrical, with a steeper east limb.

The pre-Jurassic units were weathered during the Upper Triassic and, in the east, remnants of a silicified regolith are exposed. Remnants of the exhumed peneplain are exposed around Cracow.

The Lower Jurassic to Cretaceous sediments in the Great Artesian Basin rest unconformably on the Bowen Basin sequence. They were deposited in

two basins separated by the Nebine Ridge: the Eromanga Basin in the east and the Surat Basin in the west. The sequence consists of about 350 m of Lower Jurassic non-marine sediments (Precipice Sandstone, Evergreen Formation, and Hutton Sandstone), which are overlain in the Surat Basin by about 150 m of non-marine Middle Jurassic sediments (Birkhead Formation), 120 m of non-marine(?) Upper Jurassic sediments (Westbourne Formation), 180 m of non-marine Upper Jurassic sediments (Gubberamunda Sandstone and Southlands Formation), and some 25 m of non-marine Lower Cretaceous rocks (Claravale Sandstone Member of the Bungil Formation). In the Eromanga Basin, the Hutton Sandstone is overlain by 480 m of freshwater sediments (the Jurassic Birkhead Formation, Springbok and Adori Sandstones, and Westbourne Formation, and the Jurassic to Cretaceous Hooray Sandstone). In the extreme southwest these sediments are overlain by the marine Wallumbilla Formation.

The whole sequence is apparently conformable and is gently warped over structural features in pre-Jurassic rocks. The gentle folds trend northerly in the Surat Basin, but northeasterly in the Eromanga Basin. The trends of the folds are parallel to geophysical anomalies.

Changes and additions to knowledge of the stratigraphy of the area are summarized below:

Permian: (i) The Cracow Volcanics, formerly thought to be Triassic, are part of the Lower Permian Camboon Andesite.

(ii) The lower part of the Oxtrack Formation has been recognized as a separate unit (Buffel Formation).

(iii) The Orange Creek, Passion Hill, and Acacia Formations have been equated with the Barfield Formation.

(iv) The Mount Steel Formation has been equated with the Flat Top Formation.

(v) The Bandanna Formation has been divided into the Black Alley Shale and Blackwater Group. The Black Alley Shale is the uppermost unit of the dominantly marine Back Creek Group, and is probably equivalent to the Flat Top Formation.

Triassic: The Brumby Sandstone Member has been recognized in the Serocold Anticline. In places it rests with very slight unconformity on the Blackwater Group.

Jurassic: (i) The Boxvale Sandstone is now regarded as a member of the Evergreen Formation; it wedges out to the east of the type area and thickens to the west.

(ii) The shaly lithic sandstone part of the Evergreen Formation, between the Precipice Sandstone and the Boxvale Sandstone Member, wedges out to the west of the Maranoa Anticline.

(iii) The Boxvale Sandstone Member is overlain by an oolite member, which probably represents a Lower Jurassic marine incursion into the Surat Basin, and is probably equivalent to the Westgrove Ironstone Member to the west.

(iv) Facies changes take place near the Nebine Ridge in the post-Lower Jurassic sequence. The Gubberamunda Sandstone, Orallo Formation, and Bungil Formation of the Surat Basin are indistinguishable near the ridge and are mapped as the Hooray Sandstone in the Eromanga Basin.

(v) The Injune Creek Beds have been raised to group status and subdivided into formations. The coal-bearing Birkhead Formation and the silty Westbourne Formation continue unchanged across the Nebine Ridge, but the Adori Sandstone, which lies between them in the Eromanga Basin, wedges out to the east on the Nebine Ridge.

In the Great Dividing Range remnants of Tertiary flood basalt, up to 250 m thick, rest unconformably on Permian to Cretaceous sediments. The lavas were extruded from vents and fissures now represented by basaltic plugs and dykes. Tertiary quartzose sandstone crops out in the extreme west, and thin beds of sandstone are interbedded with the basalts. The Tertiary sandstone and Cretaceous sediments in the southwest are lateritized.

Gold has been mined around Cracow since 1931, and coal near Injune since 1933. The Lower Jurassic oolitic chamositic rock is a low-grade siliceous iron ore. Twenty-two oil exploration wells have been drilled, but no deposits of commercial value have been discovered; several wells have produced large shows of gas from Permian sandstones in the Denison Trough. Good supplies of groundwater, both artesian and non-artesian, have been tapped in many bores in the area.

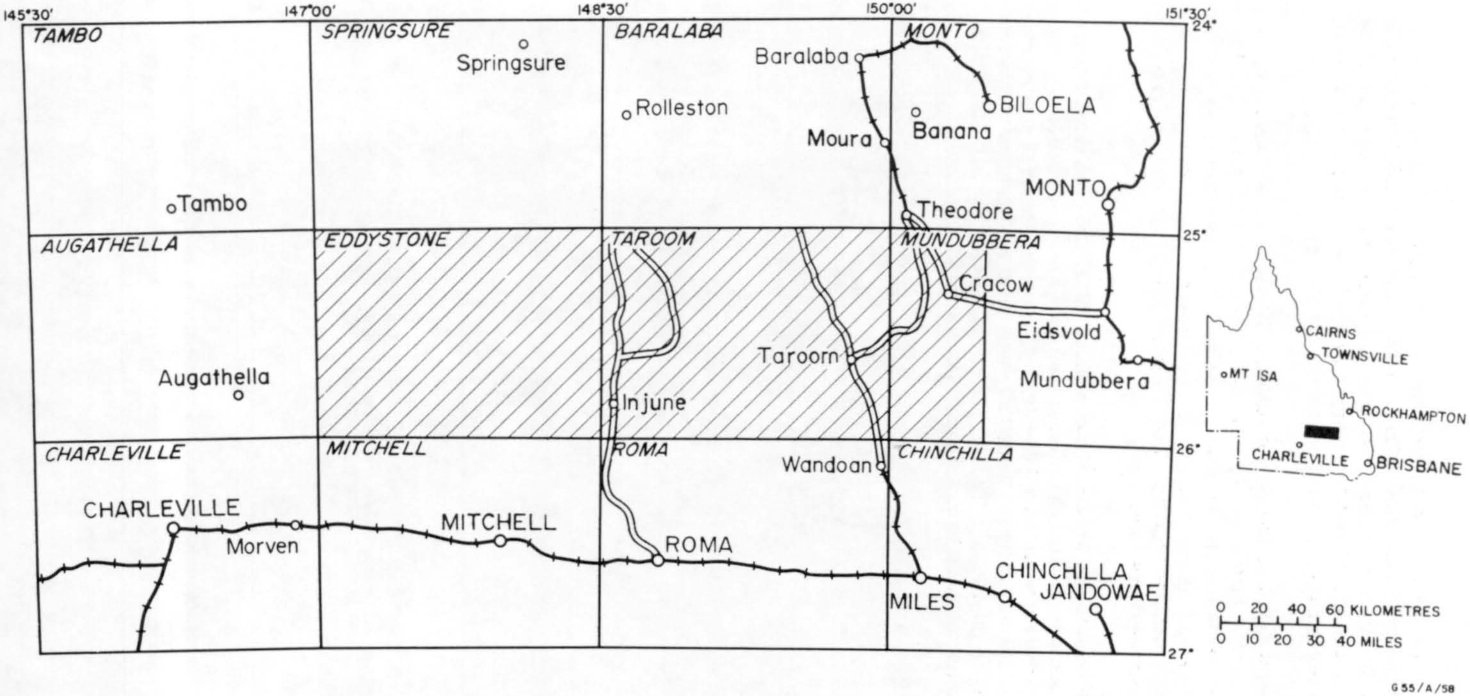

Fig. 1. Locality map and Sheet index.

INTRODUCTION

The Bureau of Mineral Resources and the Geological Survey of Queensland started to map the Bowen Basin and its environs in 1960. This Report covers the area between latitude 25°S and 26°S and longitude 147°E and 150°30'E, comprising the Eddystone 1:250,000 Sheet area, the Taroom 1:250,000 Sheet area, and the western third of the Mundubbera 1:250,000 Sheet area. The area lies at the southern end of the exposed part of the Bowen Basin and at the eastern margin of the Great Artesian Basin. Interim reports were made on the Eddystone Sheet by Mollan, Exon, & Forbes (1965, unpubl.) and on the Taroom Sheet and Mundubbera Sheet by Jensen, Gregory, & Forbes (1964, unpubl.).

Fieldwork

The Taroom Sheet and western part of the Mundubbera Sheet were mapped in 1963 by A.R. Jensen and C.M. Gregory of the Bureau of Mineral Resources and V.R. Forbes of the Geological Survey of Queensland, and the Eddystone Sheet was mapped in 1964 by R.G. Mollan and N.F. Exon of the Bureau of Mineral Resources and V.R. Forbes.

Situation and Access

The area lies about 500 km northwest of Brisbane and 80 km north of Roma (Fig. 1). Cracow, Taroom, and Injune are the three main towns; each has a population of less than 1000.

An all-weather road, the Leichhardt Highway, connects Miles to Theodore through Taroom; it is sealed from Miles to Taroom. An unsealed road, the Carnarvon Development Road, connects Roma, Injune, and Rolleston, but it is often impassable in wet weather. Good all-weather unsealed roads connect Eidsvold, Cracow, Theodore, Banana, and Moura, and good dry-weather roads link Cracow with Taroom and Wandoan. East-west access in the area is poor.

The nearest railhead, on a branch line from Miles, is Wandoan, 65 km south of Taroom. The branch line connecting Roma and Injune was closed in 1966. Two flights a week call at a gravelled airstrip 23 km south of Taroom. There are grassed strips for light aircraft at Cracow and Injune, and many of the homesteads have landing grounds.

Climate

November to March is hot and wet, and 60 to 65 percent of the rain falls in this season; April to August is cool and dry; and September and October are warm and dusty.

The average annual rainfall ranges from 550 mm in the west to nearly 750 mm in the east, and annual rate of evaporation is 825 to 1100 mm. The average daily mean temperature ranges from 11°C in July to 28°C in January; the extreme temperatures recorded are -7°C and 46°C. There are 200 to 250 frost-free days per year.

Industries

The area supports about 7800 people, most of whom are dependent on the pastoral industry. Taroom is one of the centres of the pastoral industry, but Cracow is a gold-mining town. Injune was formerly a coal-mining town, but is now a centre for farming and timber-getting.

Most of the land is used to raise beef cattle, but some sheep are run along the southern edge of the Taroom Sheet area. Some of the better soils on the Injune

Creek Beds in the Injune-Taroom area are cultivated for cereals or sown with improved pastures for fattening stock. Much of the rich black-soil country in the Dawson River Valley north of Cracow is cultivated and used for mixed farming; some areas are irrigated. The damming of the Dawson River for irrigation is under investigation.

Topography and Drainage

A generalized map of the topography and drainage is presented in Figure 2. The Great Dividing Range separates the Warrego and Maranoa River systems which drain southwards into the Darling system, from the Comet and Dawson River systems which drain northeast into the Fitzroy River. The headwaters of the Comet system are represented by the Brown River and Moolayember Creek.

Landforms are closely related to the underlying rocks. Plains and undulating lowlands are developed on the relatively unresistant Permian, Triassic, and Jurassic calcareous sandstones and mudstones. Examples of this type of terrain are the plains around Taroom, and the area of outcrop of the relatively soft Roma Formation in the extreme southwest. In sharp contrast, the most rugged topography is that produced by the Lower Jurassic sandstone and Tertiary basalt, particularly in the Carnarvon, Expedition, and Great Dividing Ranges. In these areas, where there are peaks up to 1000 m above sea level, the dominant landforms are deeply dissected plateaux, and narrow steep-sided ravines. Intermediate between the deeply dissected plateaux and the lowlands are areas of moderately dissected low plateaux and hills mainly developed on Jurassic sediments. The gently rolling highland topography with moderate hill-slopes of the Auburn Range area in the extreme eastern part of the area is underlain by Palaeozoic plutonic and volcanic rocks.

Nomenclature

Packham's (1954) classification of arenites, as modified by Crook (1960), is used throughout this Report. 'Arenite' is used as the non-genetic term for sand-sized clastic material; it contains 75 percent or less of material finer than 30 microns. If quartz forms more than 90 percent of the clasts it is quartzose; if between 75 and 90 percent, sublabile; and less than 75 percent, labile.

Labile arenites are named according to the ratio of feldspar fragments (F) to other labile fragments (R). In a feldspathic arenite F/R is greater than 3; in lithofeldspathic arenite F/R is between 3 and 1; in feldspatholithic between 1 and 1/3; and in lithic less than 1/3. Where possible, the non-genetic term 'arenite' is replaced by the genetic terms greywacke or sandstone. A volcanolithic sandstone is one composed mainly of fragments of volcanic rock.

Siltstone is used as a measure of grainsize (1/16-1/256 mm). The term mudstone is used as a general term for non-fissile sediments of the lutite class, and shale is defined as a fissile mudstone. Claystone is used for sediment consisting dominantly of clay minerals. An argillite is hard mudstone.

Acknowledgments

Our thanks are due to Shell Development (Australia) Pty Ltd for permission to use the mapping of J.B. Woolley in the Arcadia area.

Previous Investigations

R.L. Jack visited the Eddystone Sheet area in 1885 in the course of groundwater investigations. Ball reported on a mound spring at Crystalbrook in the Eddystone Sheet area (Ball, 1918), and later reported on seepages of coal gas at Cockatoo

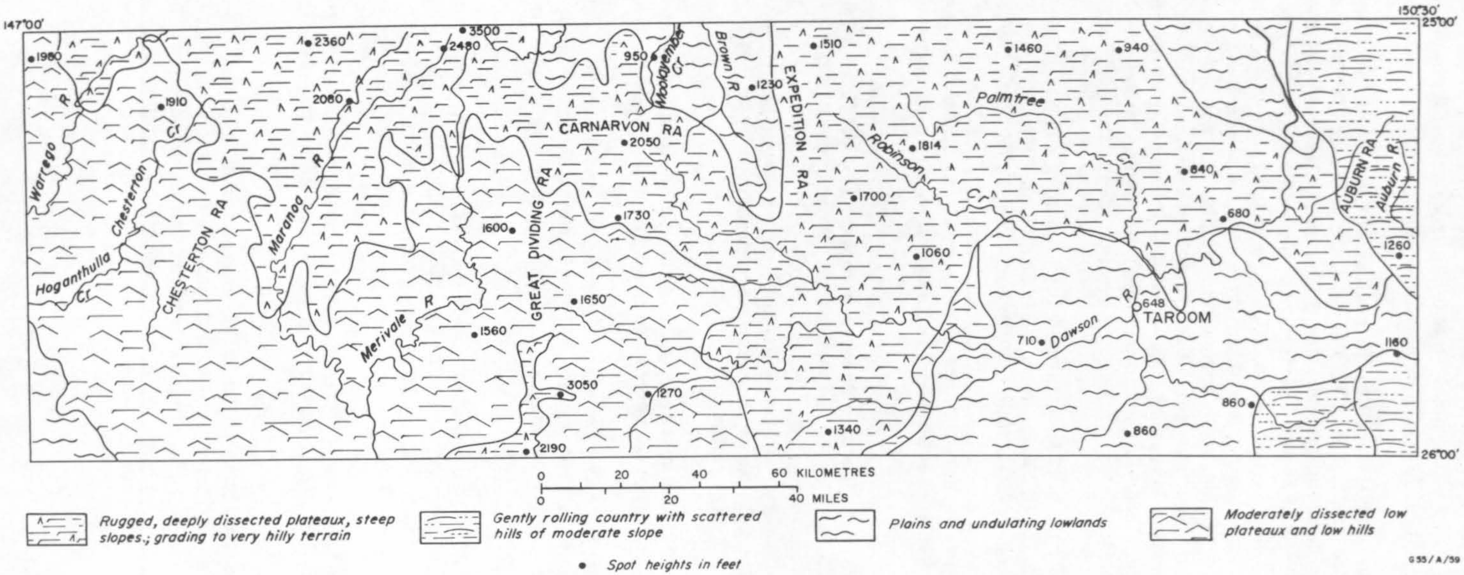

Fig. 2. Generalized topography and drainage.

Creek in the Mundubbera Sheet area (Ball, 1924). He collected small molluscs identified as Unio and fragments of the plant Thinnfeldia from sandstone which he presumed to be part of the Upper Triassic Bundamba Series.

H.I. Jensen (1921, 1926) described the geology of the area between Roma, Springsure, Tambo, and Taroom, and mapped Permo-Carboniferous ('Middle and Upper Bowen'), Triassic ('Clematis, Ipswich, and Bundamba'), Jurassic ('Lower, Middle, and Upper Walloon'), and Lower Cretaceous sediments and younger basalt in the Eddystone and Taroom Sheet areas. He mentioned the occurrence of serpentine and asbestos at Eddystone Vale and suggested the presence of a north-south ridge of metamorphic rocks under the Mesozoic sediments. He also recognized the Serocold Anticline. Around Cracow he distinguished the following units on his map: Auburn River Complex, Undifferentiated Volcanics, Lower Bowen, Permo-Carboniferous, Clematis, Ipswich, Bundamba, and Walloon formations; he also described the lithology, topography, soil, and vegetation.

The discovery of gold in 1931 at Cracow led to many geological investigations of the mine and its environs (Ball, 1931; Reid, 1931; Denmead, 1931a,b, 1932, 1933, 1937, 1938, 1939, 1946; Bonner, 1952; Buley, 1953; Brookes, 1959, 1960, 1965).

Reid (1930) mapped the Serocold Anticline in detail and subdivided the Permian rocks into formations. Denmead examined and reported on an oil shale occurrence (Denmead, 1943).

The western part of the Taroom Sheet was surveyed by Oil Search Ltd in 1933-39 (Reeves, 1935, 1936a,b; Reeves & Condit, 1935; Condit, 1936; Whitehouse, 1935a,b, 1936, 1938). These investigations led to a better understanding of the Triassic and Jurassic sequences in this area and the delineation of two structures on which OSL No. 2 (Hutton Creek) and OSL No. 3 (Arcadia) were drilled. Reeves (1947) summarized the results of oil exploration in the area.

The results of a regional survey of the Great Artesian Basin by Whitehouse were presented in a number of general reports and maps (Whitehouse, 1941, 1952, 1954).

Shell (Qld) Development Pty Ltd started geological investigations west and northwest of the Taroom Sheet in 1940, and in 1942 the Permian sequence in the western part of the Mundubbera Sheet area was examined. This sequence was mapped in greater detail in 1954 by Derrington, Glover, & Morgan (1959).

Since 1959 the results of oil exploration in the Taroom/Cracow area have been recorded in many unpublished reports (Traves, 1959; Webb, 1961; Laing, 1961; Williams, 1962). Other companies investigated coal prospects (King, 1961) and a low-grade iron ore deposit (Urquhart, 1962).

Much of the area mapped is covered by aeromagnetic, seismic, and gravity surveys (Figs 16, 17, 18, 21, 22, 23), most of which were carried out by oil exploration companies.

Twenty-two wells have been drilled in the search for oil and gas. The location of the wells is shown on Plates 3, 4, 5; lithological and electrical logs of the Jurassic sequence in some of the wells are presented in Plate 1, and a general summary of each well is given in Table 1. Several wells have encountered commercial quantities of gas. The completion reports of the subsidized wells are available at the Bureau of Mineral Resources.

TABLE 1: SUMMARY OF OIL EXPLORATION WELLS

Name of Well	Sheet Area	Year Drilled	Subsidized	Total Depth (ft)	Hydrocarbon Shows	Status
ARO No. 9 (Gunnewin) (GSQ, 1960)	Eddystone	1928-30	No	2,104	Gas reported from 1140', 1485', 1590', 1682', and 1772' (all non-petroliferous gas shows); doubtful very small oil shows below 950' to bottom	Abandoned
OSL No. 2 (Hutton Creek) (GSQ, 1960)	Taroom	1935-38	No	4,688	0.013 m cfd at 2325' (3% CO_2, 89% CH_4, 8% inert gas)	Abandoned
OSL No. 3 (Arcadia) (GSQ, 1960)	Taroom	1936-39	No	6,036	Many shows of gas: 0.25 m cfd at 1187' and 2.3 m cfd at 2670' (mainly CH_4 above 2028'; mainly CO_2 below 2028')	Abandoned
SQD No. 1 (Morella) (GSQ, 1960)	Eddystone	1950-51	No	4,634	Trace of oil and gas at about 3000'	Abandoned
AAO No. 7 (Arcadia) (Derrington, 1957)	Taroom	1957	No	3,280	Nothing significant	Abandoned
AAO Glentulloch No. 1 (Minad, 1962a)	Eddystone	1961	Yes	4,083	Many shows of gas: open hole drill stem test gave 7.5 m cfd	Abandoned
AAO Westgrove No. 1 (Minad, 1962b)	Eddystone	1962	Yes	6,442	Nothing significant	Abandoned
AAO Westgrove No. 2 (Minad, 1962c)	Eddystone	1962	Yes	5,550	Gas shows: open flow potential of dry gas, 4.75 m cfd	Gas well, suspended
AAO Westgrove No. 3 (Minad, 1963a)	Eddystone	1962-63	Yes	12,663	Gas shows: 0.541 m cfd dry gas at 2748'-2802', 0.852 m cfd dry gas at 2855'-2911', 0.293 m cfd dry gas at 12,303'-12,360'	Gas well, suspended

Name of Well	Sheet Area	Year Drilled	Subsidized	Total Depth (ft)	Hydrocarbon Shows	Status
AAO Westgrove, No. 4 (Minad, 1963b)	Eddystone	1963	No	3,017	Nothing significant	Abandoned
AAO Killoran No. 1 (Minad, 1962d)	Eddystone	1962	Yes	2,350	Nothing significant	Abandoned
AAO Bandanna No. 1 (Minad, 1963c)	Eddystone	1963	Yes	4,041	Several minor gas shows	Abandoned
UKA Burunga No. 1 (Union Oil Development Corp., 1963a)	Mundubbera	1962	Yes	10,242	Little gas: 0.25 m cfd at 7889'-7911'	Abandoned
UKA Cockatoo Creek No.1 (Union Oil Development Corp., 1963b)	Mundubbera	1962-63	Yes	12,082	Nothing significant	Abandoned
AAO Kildare No. 1 (Minad, 1963d)	Eddystone	1963	Yes	5,724	Nothing significant	Abandoned
AAO Kildare No. 2 (Minad, 1963e)	Eddystone	1963	Yes	5,667	Nothing significant	Abandoned
Planet Warrinilla No. 1 (Planet Exploration Co. Pty Ltd, 1963)	Taroom	1963	Yes	6,701	Many gas shows: main shows 0.088 m cfd at 336', 0.14 m cfd at 4167'	Abandoned
Marathon-Continental Glenhaughton No. 1 (Marathon Petroleum Aust. Ltd, 1964)	Taroom	1963-64	Yes	9,418	Nothing significant	Abandoned

Name of Well	Sheet Area	Year Drilled	Subsidized	Total Depth (ft)	Hydrocarbon Shows	Status
Planet Tooloombilla No. 1 (Meyers, 1964a)	Eddystone	1964	Yes	1,750	None	Abandoned
Planet Crystalbrook No. 1 (Meyers, 1964b)	Eddystone	1964	Yes	2,061	None	Abandoned
Planet Warrong No. 1 (Meyers, 1965a)	Eddystone	1964	Yes	3,579	None	Abandoned
Planet Warrinilla No. 2 (Meyers, 1965b)	Taroom	1964	Yes	5,807	Gas shows: 0.744 m cfd at 2523'-2565', 0.33-0.5 m cfd at 2550'-2575'	Abandoned
Amoseas Cunno No. 1 (Gerrard, 1966)	Eddystone	1966	Yes	2,828	None	Abandoned

PALAEOZOIC IGNEOUS AND METAMORPHIC ROCKS

Lower Palaeozoic Gabbro

A small inlier of sheared gabbro in the centre of Eddystone Sheet area probably represents the oldest rocks exposed. The inlier is 15 km west of Darkwater homestead, near the head of a small gully which drains into the Maranoa River from the west.

The inlier consists mainly of diallage-rich gabbro closely associated with tremolite-bearing and chlorite-bearing rocks. The veins of chlorite and tremolite cutting the gabbro possibly represent metasomatic alteration products of ultrabasic rocks.

The inlier is the only exposed part of a northerly aligned basement ridge known as the Nebine Ridge (Hill, 1951; Mollan, Dickins, Exon, & Kirkegaard, 1969). The positive gravity anomaly in the vicinity of the inlier indicates that it lies near the axis of the buried ridge (see Figs 21, 22).

The inlier is overlain by about 6 m of tough greenish siltstone composed of abundant grains of iron oxide, pyroxene, chlorite, and tremolite, with very little quartz, followed by about 6 m of ferruginous sandstone containing some quartz, which in turn is overlain by the quartzose Precipice Sandstone. The relationship between the gabbro and the overlying sediments is not clear, and it is possible that the tough green siltstone is a Triassic regolith which was derived from the gabbro.

The Ordovician isotopic age obtained by the K/Ar method (A.W. Webb, pers. comm.) probably represents the age of deformation.

Palaeozoic Metamorphic Rocks

Metaquartzite and granulite are exposed in two outcrops near Camboon homestead in the western part of the Mundubbera Sheet area.

They are intruded and metamorphosed by the Auburn Complex (see p. 76). The most accessible outcrop is a small scrub-covered hill about 2.5 km southeast of Mount View homestead and about 400 m east of the road. The second outcrop is the top 9 m of Mount Coangal, west of Camboon homestead. Jensen (1926) included the 'completely recrystallized sedimentaries' near Camboon homestead in the Auburn Range Complex, but we have separated the metamorphic rocks from the Auburn Complex in this Report.

Of the four specimens examined in thin section three are metaquartzite and the fourth is a granulite. The metaquartzite is a massive equigranular rock formed by the complete recrystallization of quartz sandstone. It consists of about 90 percent quartz and up to 10 percent muscovite, with some chlorite and, in one specimen, minor corundum. One specimen has a weakly developed schistosity. The granulite is probably a recrystallized arkose. It is medium-grained and is composed of intergranular quartz (45%), microcline (30%), sodic plagioclase (15%), orthoclase (5%), and biotite (less than 1%). This rock type, in which sodic and potassic feldspars predominate, is foreign to both the Auburn Complex and the Camboon Andesite, in which calcic plagioclase predominates.

PERMIAN SEDIMENTS

The stratigraphy of the Palaeozoic sequence is summarized in Table 2. The four Permian units (Ingelara Formation, Peawaddy Formation, Black Alley Shale, and Blackwater Group) which crop out in the Serocold Anticline are described fully in

TABLE 2: PALAEOZOIC TO TRIASSIC STRATIGRAPHY

Age	Formation (map symbol)	Lithology	Thickness in Outcrop (m)	Relationships	Fossils and Depositional Environment
PRE-JURASSIC	(pJs)	Ferruginous sublabile sandstone, tough green silty fine labile sandstone	10+	Probably unconformable on Precambrian(?) gabbro; probably unconformably overlain by Precipice Sst	
TRIASSIC	Moolayember Formation (TRm)	Mudstone, lithic sandstone, lithic sublabile sandstone, conglomerate, carbonaceous shale, tuff	300-1350	Conformable on Clematis Sst	Plants, spores, acritarchs. Fluvial, possibly lacustrine in part
	Clematis Sandstone (TRe)	Pebbly quartzose sandstone, lithic sublabile sandstone, feldspathic sublabile sandstone, volcanolithic pebble conglomerate, siltstone, red mudstone	120-300	Conformable on Rewan Fm; disconformable in places	Spores, plant fragments. Fluvial
	Rewan Formation (TRr)	Brown mudstone, lithic sandstone, conglomerate	450-3500	Conformable on Baralaba Coal Measures; disconformable on Blackwater Gp in places, slight angular unconformity within formation in Arcadia area	Plants. Mainly fluvial; possibly aeolian in part
	Brumby Sandstone Member (TRb)	Conglomeratic coarse lithic sandstone	4.5-9		Fossil wood. Fluvial

Age	Formation (map symbol)	Lithology	Thickness in Outcrop (m)	Relationships	Fossils and Depositional Environment
UPPER PERMIAN	Blackwater Group (Pua)	Feldspatholithic sandstone, siltstone, shale, coal	75-90	Conformable on Black Alley Sh. Correlate of Gyranda Fm plus Baralaba Coal Measures	Abundant plants. Paludal, fluvial
	Baralaba Coal Measures (Pul)	Feldspatholithic sandstone, carbonaceous mudstone, coal, conglomerate	195-240	Conformable on Gyranda Fm	Paludal, fluvial
	Gyranda Formation (Puy)	Mudstone, lithic sandstone, tuff, minor conglomerate	480	Structurally conformable on Flat Top Fm	Plants. Fluvial
	Black Alley Shale (Puc)	Dark shale, claystone, tuff	120	Probably conformable on Peawaddy Fm. Correlate of Flat Top Fm	Plants, acritarchs. Probably partly marine, euxinic
	Flat Top Formation (Puf)	Mudstone, argillite, tuffaceous siltstone	540	Conformable on Barfield Fm	Marine shelly fossils. Marine
	Peawaddy Formation (Pup)	Carbonaceous sandy shale, siltstone, feldspatholithic sandstone in top part	150	Disconformable on Ingelara Fm. Probable correlate of Barfield Fm plus Oxtrack Fm	Marine shelly fossils, plant fragments. Shallow marine.
	Barfield Formation (Pur)	Mudstone, lithic sandstone, concretionary limestone, greywacke tuff, andesite	900	Conformable on Oxtrack Fm	Marine shelly fossils. Marine

Age	Formation (map symbol)	Lithology	Thickness in Outcrop (m)	Relationships	Fossils and Depositional Environment
UPPER PERMIAN	Oxtrack Formation (Puo)	Fossiliferous limestone, calcareous siltstone, silicified limestone	30-105	Disconformable on Buffel Fm	Marine shelly fossils. Shallow marine
LOWER PERMIAN	Ingelara Formation (Pli)	Sandy pebbly siltstone with calcareous concretions	36	Conformable on Aldebaran Sst (Springsure Sheet)	Marine shelly fossils. Marine; nearshore rapid deposition
	Aldebaran Sandstone (Pll)	Conglomerate, quartzose sandstone, siltstone, minor coal	600	Conformable on Cattle Creek Fm in subsurface	Fluviatile deltaic; mainly non-marine
	Cattle Creek Formation (Plk)	Conglomeratic sandy siltstone and silty sandstone, coquinitic limestone	510	Conformable on Reids Dome Beds in subsurface	Marine; rapid basinal deposition
	Reids Dome Beds (Plj)	Sandstone, shale, siltstone, coal	-	Base possibly penetrated in SQD 1 (Morella)	Paludal, deltaic
	Buffel Formation (Plu)	Fossiliferous limestone, silicified limestone, conglomerate	9-192	Disconformable(?) on Camboon Andesite	Marine shelly fossils. Shallow marine
	Camboon Andesite (Pln)	Andesite, dacite, pyroclastics, rhyolite, conglomerate	3000(?)	Intruded by Auburn Complex	Plants. Shallow marine

Age	Formation (map symbol)	Lithology	Thickness in Outcrop (m)	Relationships	Fossils and Depositional Environment
PALAEOZOIC (?)	(Pz)	Metaquartzite, granulite	?	Intruded by Auburn Complex	
LOWER PALAEOZOIC	(Pzr)	Mainly gabbro, altered ultrabasic rocks, chlorite rock, and tremolite veins	?		

Mollan et al. (1969), and are only briefly considered here. Three subsurface units (Reids Dome Beds, Cattle Creek Formation, and Aldebaran Sandstone) are summarized in Table 2.

The nomenclature established by Derrington et al. (1959) in the Cracow area, and our modification in the light of later mapping elsewhere (particularly in the Monto area) are shown in Table 3.

TABLE 3: STRATIGRAPHIC NOMENCLATURE OF THE PERMIAN-TRIASSIC SEQUENCE IN THE CRACOW AREA

Previous Nomenclature Used in the Cracow Area		Revised Nomenclature
Theodore Group	Isla Formation	Rewan Formation
	Kia-Ora Formation	Baralaba Coal Measures
	Gyranda Formation	Gyranda Formation
Back Creek Group	Mount Steel Formation	Flat Top Formation
	Passion Hill Formation	Barfield Formation
	Acacia Formation	
	Orange Creek Formation	
	Oxtrack Formation	Oxtrack Formation
		Buffel Formation
	Camboon Andesite	Camboon Andesite

The names Black Alley Shale and Blackwater Group replace Shell's upper and lower parts of the Bandanna Formation (Hill, 1957).

Permian Units in the Serocold Anticline

Ingelara Formation

The Ingelara Formation consists predominantly of poorly bedded and poorly sorted sandy siltstone grading into sandy mudstone and claystone, with clasts ranging from sand size to boulder size.

The beds are black and gypsiferous when fresh and contain much carbonized plant debris, but the weathered rocks are generally grey, with a yellow mineral (probably jarosite) on the joint planes. The sequence contains zones of ovoid calcareous concretions, up to 3 m across, particularly in the upper part. The concretions contain shells and pebbles.

The Ingelara Formation grades down into the thinly interbedded sandstone and siltstone of the Aldebaran Sandstone, and is disconformably overlain by the Peawaddy Formation. The change from poorly bedded unsorted sandy siltstone and mudstone of the Ingelara Formation to fissile well bedded shale of the lower part of the Peawaddy Formation is well exposed in Dry Creek. The boundary is marked by a thin bed of coarse poorly sorted polygenetic sandstone.

The formation is about 36 m thick in Dry Creek (Mollan et al., 1969), compared with 180 m in the Springsure Sheet area. The lithological and electric logs of the exploratory wells east and south of Reids Dome suggest that the Ingelara Formation thins and wedges out under a regional unconformity at the base of the Peawaddy Formation (Mollan et al., 1969, pl. 3A). This interpretation is supported by evidence of erosion below the Peawaddy Formation in the Springsure Sheet area at the southern end of Reids Dome, where the Catherine Sandstone wedges out and the Peawaddy and Ingelara Formations thin out to the south.

The Ingelara Formation contains a shelly marine fauna of Artinskian-Kungurian age (Fauna III of Dickins, Malone, & Jensen, 1964; see also Dickins, Appendix 1 in Mollan et al., 1969).

Peawaddy Formation

The Peawaddy Formation (Mollan, Kirkegaard, Exon, & Dickins, et al., 1964) crops out in the Serocold Anticline. It forms low ridges and cuestas and can be distinguished on air-photographs by its light tone.

The lower part is exposed only in the southern nose of Reids Dome, and consists of carbonaceous shale with intercalated sandstone and siltstone. The upper part is dominantly feldspatholithic sandstone which is pebbly and calcareous in places. In the Springsure Sheet area the top of the formation is marked by coquinitic lenses known informally as the Mantuan Productus Bed. The coquinitic lenses are not exposed in the Eddystone Sheet area, although several have been encountered in exploratory wells. The formation is overlain, possibly disconformably, by shale and clay of the Black Alley Shale. The contact is sharp, and is well exposed near the road to the Carnarvon Gorge and in Oaky Creek east of Bandanna homestead.

The Peawaddy Formation is about 150 m thick in Dry Creek and throughout the Springsure Sheet area, which is the main area of outcrop. It has been identified in the logs of exploratory wells south of the outcrop.

The lower part of the formation was probably deposited in restricted marine and paralic environments. The presence of coquinite in the sandy upper part suggests exposure to the open sea.

The shelly marine fauna is of lower Upper Permian age (Mollan et al., 1969, appendix 1).

Black Alley Shale

The Black Alley Shale (Mollan et al., 1969) is poorly exposed in low-lying country covered with clayey soil. It crops out on both flanks of the Serocold Anticline in the Springsure and Eddystone Sheet areas, and has been recognized in exploratory wells to the south. It is 100 m thick in the type section (Springsure Sheet) and ranges from 90 to 130 m elsewhere.

It was formed mainly from marine mud mixed with fine windborne volcanic ash. It consists mainly of soft black to deep olive-green shale, which is cherty and splintery in places, and is readily distinguished by the presence of beds of yellow and green greasy bentonitic clay up to about 30 cm thick. The clay has been identified as montmorillonite, and contains remnants of volcanic shards and tuff. Some of the shale contains carbonized plant debris, and a few interbeds of hard ferruginous siltstone, rarely more than 10 cm thick, may be present.

The Black Alley Shale and the overlying Blackwater Group are regionally conformable.

The basal part of the Black Alley Shale contains acritarchs (Evans, 1966b), plant fossils, and fish scales.

Blackwater Group (Malone, Olgers, & Kirkegaard, 1969)

In the Eddystone Sheet area the Blackwater Group overlies the Black Alley Shale and is overlain by the Rewan Formation. It was formerly regarded as the upper part of the Bandanna Formation (Hill, 1957). The group is thinner in the Eddystone Sheet area than in the type area (Duaringa Sheet), and is generally poorly exposed. It consists of interbedded feldspatholithic to sublabile greenish sandstone, siltstone, carbonaceous shale, and coal. The lower part is characterized by lithic sandstone, and the upper part by coal measures. Fossil logs occur at several horizons in the sandstone sequence, and the shale in the upper part is commonly crowded with carbonized plant fragments. Oil shale is associated with the coal measures in the eastern flank of the Serocold Anticline.

The group is overlain by the Rewan Formation, but the boundary is difficult to define (see p. 30).

The Blackwater Group was deposited in freshwater estuaries and swamps where accumulation of plant debris alternated with sand and silt. It is about 105 m thick in the east flank of the Early Storms Dome. Elsewhere in the Eddystone Sheet, it ranges from 75 to 130 m. It has been penetrated in exploratory wells and appears to thin south and west of the area of outcrop.

The Blackwater Group contains Upper Permian spores and plants. In the Serocold Anticline, a thin sequence of sediments between the topmost coal and the Brumby Sandstone Member of the Rewan Formation is included with the Blackwater Group: it contains Lower Triassic spores.

Permian Units in the East Limb of the Mimosa Syncline

Camboon Andesite

The Camboon Andesite extends south-southeast from the northern edge of the Mundubbera Sheet area. It was equated with the Lower Bowen Volcanics by Denmead (1931a,b, 1937, 1938). The name was published by Derrington et al. (1959), who nominated an area near Camboon homestead as the type area. Denmead (1937, 1938) also mapped a younger volcanic unit lying unconformably on the Lower Bowen Volcanics; this he named the Cracow Series and suggested that it was Triassic. We were unable to separate the Cracow Series from the Camboon Andesite by lithology or structure.

The formation underlies various landforms: black-soil plains with no outcrop, gently undulating country with moderately common outcrop, and rough country with abundant outcrop.

The Camboon Andesite consists of andesite, dacite, and rhyolite flows, pyroclastics, and conglomerate. The andesite is commonly porphyritic, and consists mainly of oligoclase-andesine and hornblende. Of the acid volcanic rocks, dacite is far more abundant than rhyolite. When fresh the dacite is generally grey or white, but the altered rocks containing fine-grained chlorite and epidote are light green. The brown, purple, and pink dacites contain hydrated iron minerals in the groundmass. Much of the dacite contains rounded inclusions of andesite and dacite and fragments of pumice. Small spherulites composed of chalcedony are common in places, and quartz veining has been noted.

Tuff and subordinate agglomerate are interbedded with the lava flows. The andesitic and dacitic crystal and lithic tuffs consist of varying proportions of plagioclase, quartz, and fragments of volcanic rock set in a fine devitrified matrix. In the agglomerate the clasts range from 30 mm to 6 m across, and the beds are usually 6 to 9 m thick, but range up to 30 m. One coarse thick bed of agglomerate contains blocks of dacite up to 6 m in diameter and blocks of granite up to 1.5 m. The granite is less mafic than the granites in the Auburn Complex (see p. 75).

The formation also contains beds of conglomerate up to 25 m thick. They consist of rounded cobbles and boulders of andesite, dacite, and granite in a sparse matrix of labile sandstone.

Laterite probably of Tertiary age is developed on the eastern part of the Camboon Andesite, near Rockybar and Dearne homesteads. It caps flat-topped hillocks up to 10 m above the general level of the plain. Some low scrub-covered hills around Cracow township are composed of a soft white kaolinitic rock resting on a tough white siliceous rock, both of which were probably formed by subaerial alteration of the Camboon Andesite.

The Camboon Andesite is intruded by at least some of the intrusions of the Auburn Complex, and is also cut by a number of microdiorite, andesite, basalt, and aplite dykes. Quartz veining and silicification have been noted at some of the contacts. It is overlain disconformably by the Buffel and Oxtrack Formations and unconformably by the Jurassic Precipice Sandstone and Evergreen Formation.

The only fossil found in this area is Glossopteris (Wass, 1962); in the Monto Sheet area there is a limestone with a Lower Permian fauna in the Camboon Andesite (J.F. Dear, pers. comm.). The formation is lithologically similar, and in a comparable stratigraphical position to the Lizzie Creek Volcanics in the Duaringa, Saint Lawrence, Mackay, Mount Coolon, and Bowen Sheet areas. The Lizzie Creek Volcanics contain Lower Permian marine fossils near the top.

The massive nature of the bulk of the formation obscures the regional structure, but the few dip measurements available and the width of outcrop suggest that the total thickness may be about 3000 m.

Buffel Formation

The Buffel Formation, which was formerly considered to be part of the Oxtrack Formation, is a Lower Permian marine unit consisting mainly of fossiliferous calcarenite and coquinite with some beds of chert. It probably overlies the Camboon Andesite disconformably and is overlain disconformably by the Oxtrack Formation.

Nomenclature and Distribution: The name 'Buffel' was first used for beds at the base of the Oxtrack Formation in the Cracow homestead area, which have a significantly older marine fauna than that of the Oxtrack Formation, and consist dominantly of limestone (Wass, 1962, 1965). In the Mundubbera Sheet area, the formation crops out at Buffel Hill near Cracow homestead; at Roses Pride gold mine, 5 km northwest of Cracow township; and at Mount Ox, in the north. It generally forms strike ridges up to 30 m high, but at Roses Pride mine it only crops out at the base of the ridge, which is formed mainly by the Oxtrack Formation. The formation does not crop out in the Taroom Sheet area.

Lithology: The Buffel Formation consists mainly of fossiliferous limestone which grades laterally and vertically into hard white aphanitic chert or silicified limestone. The best and thickest exposure is in a long ridge a kilometre west of Cracow homestead, where fine to coarse-grained massive to thick-bedded richly fossiliferous dark limestone crops out. The base of the formation, about 0.75 km northwest of this locality, consists of a pebble conglomerate with a distinctive grey fossiliferous limestone matrix. The pebbles are round and up to 10 cm in diameter; they consist of brown porphyritic andesite(?). In this locality the limestone is overlain by about 15 m of blue-green hard mudstone which has a splintery fracture and contains small lenses of dark blue-grey calcilutite. Near Buffel Hill, the limestone grades vertically into hard white fossiliferous chert or silicified limestone.

At the abandoned Roses Pride gold mine, 5 km northwest of Cracow township, porphyritic brown andesite is overlain by 9 m of moderately thick-bedded coarse-grained brown fossiliferous limestone of the Buffel Formation. It contains round and angular pebbles of volcanic rocks which were presumably derived from the Camboon Andesite. Brachiopods and pelecypods (especially the thick shelled Eurydesma) are common, but a kilometre to the north large gastropods, which weather out as single specimens, are common.

Farther north, at Mount Ox, the Buffel Formation consists of a medium to coarse hard white silicified limestone, with abundant marine fossils in places; the base is covered by soil and talus.

Thickness: A thickness of over 60 m was measured, but the top of the formation was not seen. Wass (1965) estimated a thickness of 640 feet (190 m). The thickness is 9 m at Roses Pride mine and 15 m at Mount Ox.

Structure and Relationships: The Buffel Formation overlies the Camboon Andesite. The contact is probably disconformable: the lithology changes abruptly from a volcanic to a limestone sequence, and pebbles at the base of the formation appear to be derived from the Camboon Andesite. The formation was probably deposited in depressions in the volcanic terrain.

There is an appreciable time break between the deposition of the Buffel Formation and the overlying Oxtrack Formation (Appendix 2), but no angular discordance has been observed.

Environment of Deposition: The Buffel Formation was deposited in a neritic environment. The abundance of pelecypods with relatively large shells, such as Deltopecten and Eurydesma, may indicate near-shore conditions. Eurydesma in large numbers is believed to indicate a cold shallow marine environment (Dickins, 1957).

Age: Marine fossils (see Appendix 2) indicate a Lower Permian age (late Sakmarian or early Artinskian).

Oxtrack Formation (Derrington et al., 1959)

The Oxtrack Formation consists of fossiliferous limestone which grades into calcareous fossiliferous siltstone. The formation rests unconformably on the Buffel Formation and Camboon Andesite.

Distribution and Lithology: The formation crops out prominently in an almost continuous ridge from the northern edge of the area to Cracow homestead. Near Cracow township the ridge is locally known as Fossil Ridge.

In the type area, Oxtrack Creek, the formation consists of richly fossiliferous brown flaggy limestone which grades laterally into calcareous fossiliferous siltstone. The fossils include brachiopods, pelecypods, bryozoans, corals, and crinoid stems. The most distinctive feature of the limestone is the abundance of crinoid ossicles, up to 2.5 cm in diameter, and crinoid stems up to 18 cm long.

At Mount Ox, north of the type area, the limestone is represented by fossiliferous chert, and farther south, at Roses Pride mine, the limestone is similar to that in the type area, but is strongly silicified at the top of the ridge.

Southwest of Cracow homestead, in Ross Creek, the formation is well exposed in a small syncline. Here it consists mainly of fossiliferous calcareous mudstone which grades laterally into coquinite. The variety of limestone found in the type area was not seen in this section, but the shelly mudstone changes laterally into limestone along strike.

The basal part of this section is distinguished by the presence of hard white lithic sandstone and interbedded siltstone which have not been observed elsewhere. Neither the top nor the base of the formation is exposed in this section.

Structure and Relationships: The main reason for distinguishing the Buffel Formation from the Oxtrack Formation is the difference in faunal content, which indicates a considerable depositional break between them. Although the difference in lithology is generally small, the two formations can generally be distinguished at any one place. There appears to be no angular discordance between them.

The Oxtrack Formation rests disconformably on the Buffel Formation or Camboon Andesite, and is conformably overlain by the Barfield Formation. From Mount Ox in the north to a few kilometres south of Cracow township, it dips consistently to the west at about 20°. In the Cracow homestead area it is folded into an anticline, in the core of which Camboon Andesite is exposed.

The formation has a maximum thickness of 105 m in the Cracow homestead area. Farther north, at Roses Pride mine and Mount Ox, it is about 30 m thick.

Environment of Deposition: The contrast between the marine faunas in the Oxtrack and Buffel Formations may reflect both a difference in age and a different environment of deposition. For example, the abundance of small corals may show that the Oxtrack Formation was laid down in warmer water than the Buffel Formation.

Age: Lower Upper Permian (Kazanian) (see Appendix 2).

Barfield Formation

The Barfield Formation rests conformably on the Oxtrack Formation. It consists of about 900 m of massive mudstone with calcareous concretions, calcareous lithic sandstone, tuff, agglomerate, and at least one andesite flow.

Nomenclature: Derrington et al. (1959) named the units in the Cracow area between the Oxtrack Formation and the Mount Steel Formation the Orange Creek, Acacia, and Passion Hill Formations. In the Banana area, they defined the Barfield and Flat Top Formations, which rest conformably on the Oxtrack Formation. We equate the Mount Steel Formation with the Flat Top Formation, and the Barfield Formation with the Orange Creek, Acacia, and Passion Hill Formations, on lithological grounds.

Distribution and Topography: The Barfield Formation occupies a belt extending from the northern boundary of the Mundubbera Sheet area to the centre of the Sheet, where it is overlain by Mesozoic sediments. The formation crops out poorly, and generally occupies a valley between ridges of the Oxtrack and Flat Top Formations. The base is best seen on the western slopes of Mount Ox. The middle portion is generally covered by black soil, but some indication of the lithology was obtained from BMR Mundubbera No. 30 and No. 31 (Arman, 1965). The top part of the sequence is well exposed in a small creek about 1.5 km north of Mount Steel.

Lithology: The lithological sequence is presented in Figure 3. For explanation of symbols and abbreviations used in columnar sections, see Fig. 4). Dark-coloured mudstone, in places calcareous, is common throughout the formation, and it appears to be the only rock type present in the lower part. The carbonate may be disseminated throughout the mudstone beds, or concentrated in irregular lenses of calcilutite, or in spherical concretions up to 30 cm in diameter. Although fossil brachiopods, corals, bryozoans, or crinoid stems form the nucleus of many concretions, their most common mode of occurrence is in thin layers within the mudstone. Glendonites (carbonate pseudomorphs after glauberite) also form the nucleus of some of the concretions.

In the upper part of the formation the mudstone is interbedded with lithic arenite, tuff, agglomerate, and at least one bed of volcanolithic pebble conglomerate.

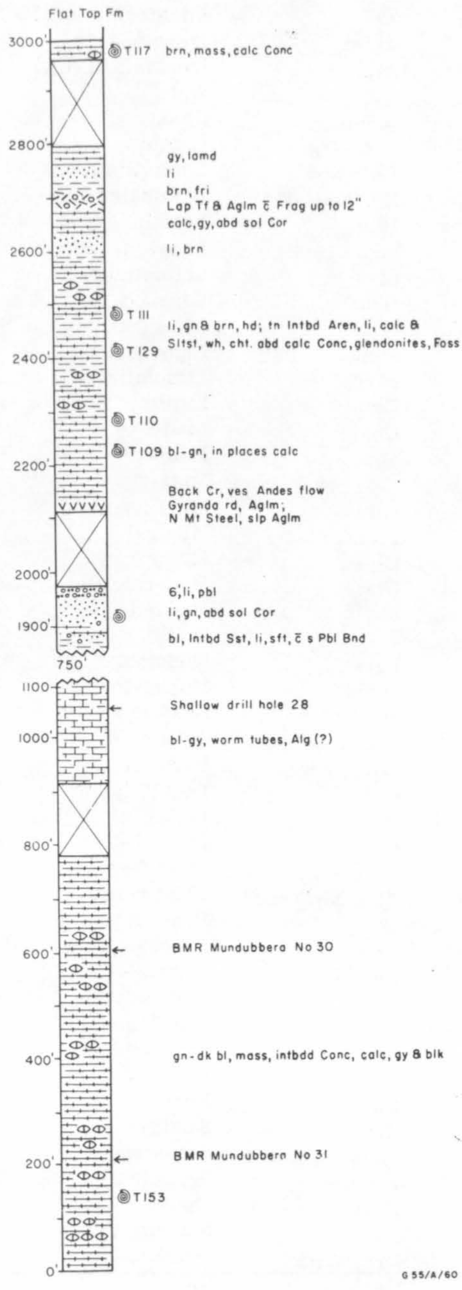

Fig. 3. Composite section of the Barfield Formation in the Cracow area.

ABBREVIATIONS

Abundant	abd	Intraformational	intfm
Agglomerate	Aglm	Ironstone	Fest
Algae	Alg	Ironstained (ing)	festnd, Festng
Angular	ang	Joint	Jt
Arenite	Aren	Khaki	kh
Argillite (aceous)	Arg, arg	Labile	lab
Band (ed)	Bnd, bndd	Lamellibranchs	Lbr
Bed (ing) (ed)	Bd, Bdg, bdd	Laminated	lamd
Biotite	Biot	Lapilli	Lap
Black	blk	Large, largely	lrg
Blue	bl	Lateritized	latd
Breccia	Brec	Leached	lchd
Brown	brn	Lens (ticular)	Len, len
Calcareous	calc	Light (er)	lt
Carbonaceous	carb	Limonitized	lmnd
Cement	Cmt	Lithic	li
Chalcedony	Chalc	Little	ltl
Chamositic	chm	Massive	mass
Chert (y)	Cht, cht	Matrix	Mtx
Choritic	chl	Mica (ceous)	Mic, mic
Clast (ic)	Clast, clast	Mineral	Mnrl
Clay (ey)	Cl, cl	Minor	mnr
Claystone	Clst	Moderate (ly)	mod
Clean	cln	Mottled	mtl
Coarse (ly)	c	Mud	Md
Common (ly)	com	Mudstone	Mdst
Concealed	cncld	Muscovite	Musc
Concentric (ally)	cncn	Near (ly)	nr
Conchoidal	conch	Oolitic	ool
Concretion (ary)	Conc, conc	Parallel	par
Conglomerate	Cgl	Pebble (y)	Pbl, pbl
Contorted	cntd	Pellet (al)	Pel, pel
Corals	Cor	Pink	pk
Cream (y)	crm	Plant fossils	Plt Foss
Cross-bed (ing) (ed)	Xbd, Xbdg, xbdd	Plant remains	Plt Rem
Dark (er)	dk	Poor (ly)	p
Exposed	expd	Porous	por
Feldspar (thic)	Fld, fld	Probable (y)	prob
Ferruginous (ized)	fe, fed	Purple (ish)	purp (purp)
Strongly ferruginized	fed (underlined)	Quartz (ose)	Qz, qzs
Fine (ly)	f	Quartzite	Qzt
Flaggy	flg	Reddish	(red)
Flake	Flk	Rock	Rk
Flattened	flatd	Sand (y)	Sd, sd
Fossil (iferous)	Foss, foss	Sandstone	Sst
Fracture	Frac	Sediment	Sed
Fragment	Frag	Shale	Sh
Friable	fri	Siderite (ic)	Sid, sid
Grain (ed)	Grn, grnd	Silicified	si
Granule	Grnl	Silty	slt
Green (ish)	gn, (gn)	Siltstone	Sltst

Fig. 4. Symbols and abbreviations used in columnar sections.

Grey	gy	Slumped	slp
Hard	hd	Small	s
Heavy	hvy	Soft	sft
Hematite	Hem	Solitary	sol
Impermeable	imperm	Sorted	srtd
Interbed (ed)	Intbd, intbdd	Specific gravity	SG
Subangular	subang	Vesicular	ves
Sublabile	sublab	Volcanics	Volc
Thin	tn	Weathered	wthrd
Tuff	Tf	Well	w
Uniform	uni	White	wh
Very	v	With	$\bar{c}$
		Yellow	yel

SYMBOLS

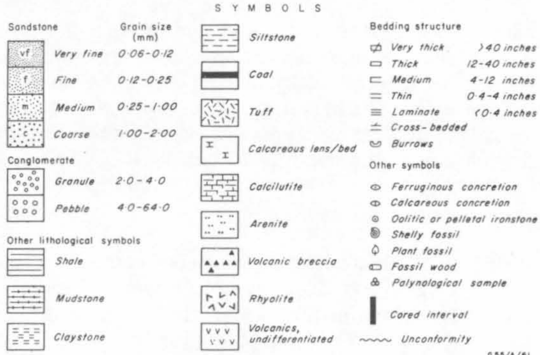

Fig. 4 (cont'd)

The tuff is composed of lapilli-sized lithic fragments and forms at least two beds each about a metre thick; it is associated with minor volcanic agglomerate. A vesicular lava flow, which crops out about 630 m stratigraphically above the base of the formation, is well exposed at Back Creek. Farther north, on the Gyranda-Cracow road, and in a creek 1.5 km north of Mount Steel, the flow is brecciated, and at the latter locality the enclosing sediments are slumped and brecciated.

Structure and Thickness: The Barfield Formation is conformable between the Oxtrack and Flat Top Formations. The regional dip is to the west at 15° to 30°. In places the beds have been disturbed by northeasterly faults, such as the one southeast of Binda Weir, where the dip is to the southeast on the northern side of the fault. The formation is involved in the folding at Cracow homestead.

The thickness in Back Creek and near Mount Steel is about 900 m.

Environment of Deposition: The Barfield Formation is undoubtedly marine. Many of the fossil fragments are broken and worn. The significance of the glendonites is unknown. It has been suggested by Whitehouse (1932) that they are associated with glacial or subglacial climates. The lack of current structures probably indicates that the formation was deposited in deep water, and the presence of black pyritic mudstone indicates a reducing environment. The bryozoans and crinoids were probably brought into the area by short-lived strong currents.

Age: The age is lower Upper Permian (Kazanian) (see Appendix 2).

Flat Top Formation (Derrington et al., 1959)

The Flat Top Formation, which conformably overlies the Barfield Formation, consists mainly of fine-grained clastic and tuffaceous sediments.

Nomenclature and Distribution: In the type area in the Monto Sheet area the sequence consists of 225 m of moderately indurated fine to coarse-grained light grey calcareous feldspatholithic sandstone interbedded with olive-green to blue-grey mudstone and hard limestone. In the Cracow area, the formation above the Passion Hill Formation (in this Report, the top of the Barfield Formation) was named the Mount Steel Formation (Derrington et al., 1959). It was defined as a sequence of grey to olive-green mudstone, siltstone, and sandy siltstone, but to the north of Mount Steel it was reported to change into a more muddy facies. We include the Mount Steel Formation with the Flat Top Formation on lithological grounds.

The formation crops out in discontinuous strike ridges, up to 60 m high, from the northern boundary of the Mundubbera Sheet area to a locality about 1.5 km north of Downfall Creek. In sharp contrast, the underlying Barfield Formation forms flat country. This change in topography is obvious on the air-photographs.

Lithology: In the Cracow area the formation is composed of hard buff and blue mudstone which grades laterally into buff-coloured argillite. It is interbedded with poorly sorted lithofeldspathic sandy siltstone which contains a high proportion of primary volcanic detritus. The base of the sequence is well exposed in places, but is generally concealed. The vertical lithological changes are slight, and it consists mainly of tough mudstone or argillite with an intricate pattern of contorted blue laminae. The structures, most of which are less than a centimetre thick, were probably produced by slumping, but they may be organic in origin. A large-scale slump structure, 3 m thick and about 9 m long, was observed 3 km northeast of Gyranda.

Impressions of wood fragments are common towards the top of the formation, but no leaf impressions were seen.

Structure and Thickness: The Flat Top Formation dips west at 12° to 25°. It conformably overlies the Barfield Formation, and the contact is exposed in a small creek about 1.5 km north of Mount Steel. The contact with the overlying Gyranda Formation was not seen, but is thought to be conformable. There appears to be a slight divergence of strike between the two units east of Gyranda, but the detailed structure is obscured by Tertiary sediments, and the divergence may be due to a slight change in dip along the strike.

The formation is about 550 m thick. The Mount Steel Formation was estimated by Derrington et al. (1959) to be 420 m thick.

Age: The age is lower Upper Permian (Kazanian) (see Appendix 2).

Environment of Deposition: The Flat Top Formation contains a few marine fossils, but they are not as abundant as in the type area and Baralaba Sheet area, probably because of a slight change of depositional environment. Fossil wood impressions are common towards the top, and coal seams were encountered in the Cockatoo Creek No. 1 well. The decrease in marine fossils and the increase of plant material may indicate a general shallowing of the sea from north to south.

The current structures give no indication of the depth of water. Cross-stratification is absent, but this may be because of the fine grainsize of the sediments, rather than the absence of traction currents. The fineness of the sediments may also account for the presence of slump structures.

Gyranda Formation (Derrington et al., 1959)

The Gyranda Formation consists of mudstone, lithic sandstone, tuff, and minor conglomerate. It contains well preserved Permian plants, and is conformably overlain by the Baralaba Coal Measures, and probably rests conformably on the Flat Top Formation, although the contact is not exposed.

Distribution: The type area is in Back Creek, near Cracow. The formation crops out only in the Mundubbera Sheet area, in a strip extending from the northern boundary to a locality west of Cracow homestead; to the south it is covered by Jurassic sediments. It has been recognized in the Burunga No. 1 and Cockatoo Creek No. 1 wells, but not in the wells in the western part of the Taroom Sheet area.

Lithology: The Gyranda Formation is composed of mudstone, lithic sandstone, calcareous lithic sandstone, fine tuff, and minor siltstone, conglomerate, and volcanic breccia. The mudstone is thinly laminated, green to brown, and commonly contains abundant carbonized plant debris. The sandstone is generally green to brown, and has a blocky fracture. It is almost invariably trough cross-bedded, and is composed mainly of volcanic detritus and other lithic fragments. In places the sandstone has a carbonate cement. Pebble conglomerate, composed of round pebbles of volcanic rock, is not common, but hard white and brown fine-grained cherty tuff, with well preserved fossil leaf impressions, is common at the top of the formation.

The general sequence is shown in a composite section based on field observations in the Cracow area (Fig. 5). The lower part of the sequence crops out near the pumping station at Gyranda, and can also be recognized in the logs of the Cockatoo Creek No. 1 and Burunga No. 1 wells. The base of the overlying Baralaba Coal Measures is taken at the lowest coal seam or shale rich in carbonized plant material.

Structure and Thickness: In the Mundubbera Sheet area the formation has a regional dip to the west of 10° to 22°. It lies conformably beneath the Baralaba Coal Measures, the subsurface extent of which is known reasonably well from seismic surveys. The thickness is estimated as 480 m.

Age: Upper Permian (see Appendix C).

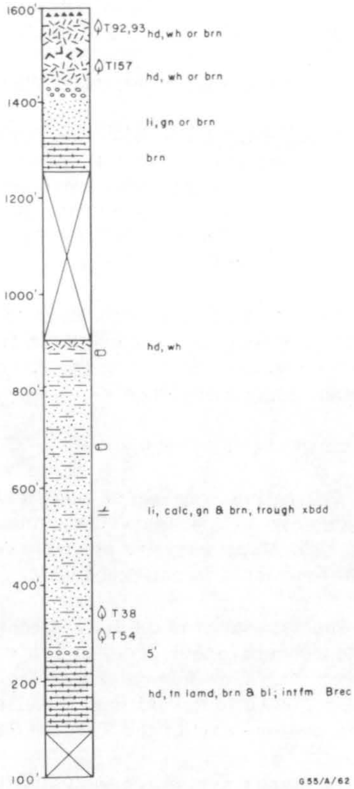

Fig. 5. Composite section of the Gyranda Formation.

Environment of Deposition: The formation is probably fluvial or deltaic. It contains an abundance of fossil plants but no marine fossils.

Baralaba Coal Measures (Olgers, Webb, Smit, & Coxhead, 1966)

The Baralaba Coal Measures are 200 to 240 m thick in the outcrop area; they consist of feldspatholithic sandstone, carbonaceous mudstone, and coal.

Distribution: The Baralaba Coal Measures crop out poorly in a number of low strike ridges along a narrow belt extending from the northern boundary of the Mundubbera Sheet area to southwest of Cracow homestead. They can be recognized in the Cockatoo Creek No. 1 and Burunga No. 1 wells. Coal measures are also found in the equivalent part of the section in the wells in the western part of the Taroom

Sheet area, where the distribution has been delineated by seismic reflection surveys.

Lithology: Outcrops are poor and scattered; the most accessible are at Hilltop homestead, 24 km northwest of Cracow township, and near Kia Ora homestead, 10 km north of Hilltop.

The formation consists of carbonaceous mudstone which in places grades into carbonaceous shale, medium to coarse-grained trough cross-bedded feldspatholithic sandstone, coal, and minor lithic sublabile sandstone. The coal is known only from bores (King, 1961). King reported a facies change along strike from sandstone in the north to a more argillaceous facies in the south.

The formation is distinguished from the underlying Gyranda Formation by the presence of coal and by the absence of beds of hard white tuff. The lower boundary has been taken at the lowest, and the top at the highest, coal seam in the sequence; in the Cracow area the upper boundary corresponds closely to the base of the conglomeratic sequence forming the lower part of the Rewan Formation.

Structure and Thickness: In the area of outcrop, the Baralaba Coal Measures have a regional dip to the west-southwest; the dip decreases along strike from north to south - 22° at Kia Ora homestead, and 13° farther south at Hilltop. King (1961) reported a general thinning of the coal measures from north to south: 240 m at Kia Ora homestead to 200 m west of Dawson Vale homestead; but south of the area of outcrop, the formation thickens again to about 450 m in both the Cockatoo Creek No. 1 and Burunga No. 1 wells. The equivalent coal measures in the subsurface in the western part of the Taroom Sheet are only about 90 m thick.

The subsurface structure has been delineated by seismic surveys (Fig. 24) over much of the southern half of the Bowen Basin. The formation is exposed on the eastern limb of the Mimosa Syncline, and, though it does not crop out in the western limb, it must be close to the surface. It is more tightly folded and faulted on the Comet Ridge west of the Mimosa Syncline.

Age: In other parts of the Bowen Basin the Baralaba Coal Measures contain a Permian flora.

Environment of Deposition: The Baralaba Coal Measures were laid down in freshwater swamps.

TRIASSIC SEDIMENTS

The Triassic Mimosa Group, comprising the Rewan Formation, Clematis Sandstone, and Moolayember Formation, extends southwards from the Bowen Basin into the Surat Basin. The name Cabawin Formation was introduced by Union Oil Development Corporation in the completion report on the Cabawin No. 1 well (Union, 1963d), and was first published by the Geological Survey of Queensland (1960-65). The formation was correlated with the Mimosa Group. Mack (1963) later mapped the same interval in the Baralaba, Springsure, and Taroom Sheet areas as the Cabawin Formation, which included 'tongues of Clematis Formation'. Petrological (Fehr & Bastian, 1962) and palynological (Evans, 1964b) investigations have shown that the Cabawin Formation as originally defined in Cabawin No. 1 is equivalent to the lower part only of the Rewan Formation.

Rewan Formation (Mollan et al., 1969)

The Rewan Formation crops out in the Serocold Anticline in the Springsure Sheet area and northeast corner of the Eddystone Sheet area. It also crops out in the northwestern and northeastern corners of the Taroom Sheet area and in the northwestern corner of the Mundubbera Sheet area. It consists of lithic sandstone, in places pebbly, interbedded with reddish brown mudstone and conglomerate. A prominent pebbly sandstone bed, the Brumby Sandstone Member, occurs towards the base of the formation in the Arcadia Anticline (northwestern part of Taroom Sheet), and at the base in the Serocold Anticline. The upper part crops out very poorly, because of the abundance of reddish brown mudstone.

Distribution: The Rewan Formation crops out in the northeast corner of Eddystone Sheet, in the Arcadia Valley (Taroom Sheet), and in a long strip west of the Dawson River in the Cracow area (Mundubbera Sheet). It generally underlies flat country with a few gentle rises and strike ridges. The Brumby Sandstone Member, however, forms a steep hill in the Arcadia area and several pronounced ridges in the Serocold Anticline. In the Arcadia Valley the formation crops out poorly. The top is almost invariably obscured by sand derived from the Clematis Sandstone. It can be seen, however, in the gap cut in the Clematis Sandstone by Moolayember Creek, on the Carnarvon Highway, and in several places along the west flank of the Serocold Anticline.

The formation has been recognized in all the oil exploration wells except OSL No. 2 (Hutton Creek), Tooloombilla No. 1, and Killoran No. 1. It has only been tentatively recognized in Glentulloch No. 1 and Crystalbrook No. 1 (Mollan et al., 1969, pls 3A, 3B).

Lithology: In the Arcadia area and the northeastern part of the Eddystone Sheet area the Rewan Formation consists of lithic sandstone interbedded with reddish brown mudstone. In places the sandstone is mottled as a result of carbonate cementation, and is characterized by the presence of brown round mud clasts. A distinctive coarse sandstone, the Brumby Sandstone Member, forms the ridges to the west of the Arcadia wells, and in the Serocold Anticline. It is a poorly sorted dense tough mottled pebbly sandstone containing fragments of volcanic rock and grains of green chert.

Most of the formation, especially the upper part, consists of reddish brown mudstone, though it has been called brown or chocolate shale. It is invariably massive, and shows no current structures or stratification; in contrast, the sandstone is commonly cross-stratified.

In the Cracow area, the base of the formation is marked by a volcanolithic conglomerate, overlain by pebbly lithic sandstone interbedded with brown mudstone. Like the sandstone of the Arcadia area, the pebbly sandstone has, in many places, a carbonate cement. The mudstone in both areas is non-calcareous.

Definition of Top and Base: Near Rewan homestead and in the Serocold Anticline, the base of the Rewan Formation is the base of the Brumby Sandstone Member; where the member is absent it is above the highest bed of coal in the underlying coal measures (Mollan et al., 1969).

In the Arcadia area, Shell geologists nominated the Brumby Sandstone (their Malta Grit) as the base of the Rewan Formation, because no brown mudstone crops out below it, and because of minor unconformity with the underlying sediments. But AAO No. 7 (Arcadia), which began below the Brumby Sandstone Member, encountered in the first 90 m calcareous quartz sandstone and grey micaceous shale interbedded with mottled grey-green and chocolate shales (Derrington, 1957), which are presumably part of the Rewan Formation. For this reason, and despite the fact that there is a slight angular discordance near the base of the Brumby Sandstone, we tentatively include the sediments between the Brumby Sandstone and the highest coal of the underlying coal measures in the Rewan Formation. Possibly, as indicated in Warrinilla No. 1, later mapping will prove that another formation can be recognized in this interval.

The thin interval between the Brumby Sandstone Member and the highest coal in the Serocold Anticline area is included in the Blackwater Group, because it is easier to map the base of the resistant Brumby Sandstone Member than the poorly outcropping highest coal seam. This procedure introduces very little error because the interval is so thin, and the scale of the map so small. In the Springsure Sheet area this interval was found to contain Lower Triassic spores. An exposure in a gully 2.5 km south-southeast of Early Storms homestead shows the Brumby Sandstone resting directly on a coal seam (Mollan et al., 1969).

In the Cracow area, the base of the Rewan Formation is a thick bed of pebble conglomerate which crops out well at Hilltop homestead and near Kia Ora homestead. The bed lies above the highest coals of the Baralaba Coal Measures and below the lowest known occurrence of brown mudstone in BMR Taroom No. 25. Future work may show that this conglomerate belongs more properly to the Baralaba Coal Measures.

The top of the formation is marked by the appearance of thick beds of lithic sublabile and quartzose sandstone of the Clematis Sandstone. The contact is seen in the Taroom Sheet area in the road cutting where Moolayember Creek cuts through the Clematis Sandstone: massive green and red mudstone, interbedded with biotitic lithic sandstone, is overlain by thick beds of lithic sublabile sandstone which grades into quartzose sandstone. Although some red and brown beds of mudstone are interbedded with the more quartz-rich sandstone, the boundary between the Rewan Formation and the Clematis Sandstone is considered to be the base of the sublabile sandstone beds. Similar criteria were used to define the boundary in the northeastern part of the Taroom Sheet area. At several places on the west flank of the Serocold Anticline, the boundary is a sharp contact between reddish brown silty mudstone of the Rewan Formation and pebbly quartzose sandstone of the Clematis Sandstone.

Structure and Relationships: The Rewan Formation is regionally conformable with the underlying coal measures of the Blackwater Group and the overlying Clematis Sandstone, but the contacts are locally unconformable or disconformable. In the eastern part of the area mapped the Rewan Formation dips at about 20° to the west (one steeper dip was noted, but this may have been caused by faulting). The formation is folded in the Serocold and Arcadia Anticlines, and in several lesser folds in the west.

In the asymmetrical southerly plunging Serocold Anticline the dip in the west flank is up to 40° and in the east flank up to 10°. The Arcadia Anticline is poorly exposed, but Woolley (1944) has shown that the structure is complex. In the south, the anticline trends north, but at the northern end of the exposed structure the trend is northeast. The area has been affected by faults, most of which strike between north-northeast and north-northwest. The crest of the Arcadia Anticline may be faulted in the northern part of the exposed structure, and in the subsurface this has been confirmed by seismic surveys (Associated Australian Oilfields NL, 1962). Many of the minor structures mapped by Woolley in the Arcadia area (Woolley, 1944) are too small to be shown on Plate 4.

In the Cracow area there is no apparent angular discordance between the Rewan Formation and the Baralaba Coal Measures, but because of the scale of mapping and the lack of outcrop it cannot be stated unequivocally that a slight angular unconformity does not exist; this is true also of the upper contact with the Clematis Sandstone.

Thickness: The Rewan Formation thins rapidly from about 3500 m in the east to 390 to 750 m in the Arcadia area. In the Serocold Anticline it is about 540 m thick.

The estimate of 3500 m may not be reliable as it is based mainly on seismic evidence to the north of the area mapped (Marathon, 1963), but the few dip measurements available in the Cracow area seem to confirm it. In the Arcadia area, the lack of outcrop and complicated structure make it difficult to estimate the thickness. Woolley's (1944) observations show that the top part of the formation (his upper Rewan Series) is about 390 m thick. He reported, however, that the thickness of the lower part of the sequence ranges from 270 to 4.5 m.

The Rewan Formation is 540 m thick in the west flank of the Serocold Anticline a kilometre south of Carnarvon Creek. In the type area (east flank of Serocold Anticline, Springsure Sheet) it is 510 m thick (Mollan et al., 1969).

The Brumby Sandstone Member (Woolley's Malta Grit) is generally about 4.5 m thick in the Arcadia area and has a maximum thickness of 9 m in the Serocold Anticline.

Age: The fragments of poorly preserved fossil plants from about 5 km north-northeast of the Dawson River/Downfall Creek junction (collection T71) have been determined as Dicroidium odontopteroides (Morr.) Gothan by White (1964). Dicroidium has also been recorded in the Arcadia area, but the exact localities are not known (Whitehouse, 1935b). White considers that the age of the plant fossils is Triassic or Lower Jurassic.

Palynological evidence, however, points to a Lower Triassic age. Lower Triassic spores were found in AAO No. 7 (Arcadia), although Derrington regarded the interval from which they were taken as Bandanna Formation (Derrington, 1957). Evans (1964b) has noted the Lower Triassic age of the Rewan Formation in other areas.

Two fossil bone fragments, partly stained red, were found in surface scree on an exposure of redbeds of the Rewan Formation at the Crater in the northeastern part of the Eddystone Sheet area. They have been identified by A. Bartholomai (pers. comm.) as a caudal vertebra, probably of a thecodont reptile, and a probable reptilian rib fragment, which are probably Lower Triassic in age.

Environment of Deposition: Because it contains no marine fossils and is part of a thick pile of Upper Permian/Triassic non-marine sediments, it is assumed that the Rewan Formation was deposited in a terrestrial environment. The pebbly trough cross-bedded sandstone probably represents fluviatile deposition. The origin of the massive reddish brown mudstone is unknown.

Clematis Sandstone (Olgers et al., 1966)

The Clematis Sandstone is composed essentially of cross-stratified lithic sublabile and quartzose sandstone with minor interbedded mudstone and conglomerate. It rests conformably on the Rewan Formation, and crops out on both limbs of the Mimosa Syncline and on the western flank of an anticlinorium.

The Clematis Sandstone crops out in the Taroom and Eddystone Sheet areas. It crops out in the Carnarvon Range to the west of the Arcadia Anticline, and forms the Expedition Range to the east; it also forms the Dawson Range in the northeast corner of the Taroom Sheet area. The formation generally crops out well in rough hilly country with vertical cliffs in places.

Lithology: The formation consists mainly of thick-bedded cross-stratified lithic sublabile sandstone, which ranges from very fine to very coarse in grain, interbedded with quartzose sandstone, feldspathic sublabile sandstone, pebble conglomerate, siltstone, and reddish brown mudstone. Cross-stratification is by far the most common current structure, although irregularly contorted stratification is common in places.

Much of the sandstone, although rich in quartz, contains a matrix of brown clay(?) minerals which gives it a distinctive brown colour. Mica flakes are not uncommon. Sorting is poor to moderate, and pebble bands are common. In places the sandstone grades vertically into pebble conglomerate; most of the pebbles are quartz or quartzite. Lateral gradation to pebble conglomerate is evident at the southern end of the Dawson Range, at the headwaters of Gap Creek, where pebble conglomerate is interbedded with brown quartz-rich sandstone. The pebbles are round and up to 8 cm in diameter, and consist almost exclusively of volcanic rocks, with some small round fragments of silicified wood. The conglomerate is similar to that found in both the Rewan and Moolayember Formations. In the west limb of the Serocold Anticline the Clematis Sandstone is more quartzose and milky quartz clasts predominate in the conglomerate.

Thin beds of finer-grained sediments are not uncommon. In the basal part of the sequence there are thin beds of green mudstone and reddish brown mudstone with plant impressions. Towards the top, beds of carbonaceous shale with plant debris are present. White and grey siltstone, commonly flaggy, is found throughout the sequence.

Structure: The Clematis Sandstone is folded into the Mimosa Syncline and into an anticlinorium between the Expedition and Carnarvon Ranges. Dips are very much lower in the Expedition Range, where the regional dip appears to be less than 5° to the east. The anticlinorium consists of the asymmetrical Arcadia, Warrinilla, Morella, and Serocold Anticlines, which have steeper westerly limbs and plunge southwards. The Clematis Sandstone dips at 40° west in the west limb of the Serocold Anticline. Dips elsewhere in the anticlinorium are generally between 5° and 10°. Mapping did not reveal any angular unconformity between the Clematis Sandstone and the Rewan Formation below or Moolayember Formation above.

Thickness: A measured section of the Clematis Sandstone about 1.5 km south of Carnarvon Creek in the west limb of the Serocold Anticline is 120 m thick (Mollan et al., 1969). Elsewhere the formation apparently thickens eastwards: in the northwest part of the Taroom Sheet it is estimated to be 250 m thick; 110 km east, in the Dawson Range, it is estimated to be 300 m thick. In the type area, just north of the Taroom Sheet area, the formation is about 270 m thick (Olgers et al., 1966).

Age: No identifiable macrofossils have been recorded, but a sample from near the top of the unit in the western part of the Taroom Sheet (T227) was found to contain a Middle to Upper Triassic microflora (Evans, 1964a).

Environment of Deposition: The absence of marine fossils and the presence of plant debris suggest that the Clematis Sandstone was laid down in a terrestrial environment. The ubiquitous cross-stratification and the poor to moderate sorting and abundant pebble bands indicate that the formation was probably laid down on a subsiding flood-plain with braided river channels.

Moolayember Formation

The Moolayember Formation is the youngest unit in the thick Permo-Triassic sequence of the Bowen Basin. It consists mainly of mudstone, interbedded with lithic sandstone, lithic sublabile sandstone, conglomerate, carbonaceous shale, and tuff.

Nomenclature and Distribution: Reeves (1947) introduced the term Moolayember Shale for a sequence of Middle Triassic 'olive-green, sandy tuffaceous shale, and thin calcareous sandstone' cropping out beneath his Bundamba Sandstone (=Precipice Sandstone) and above his Carnarvon Sandstone (=Clematis Sandstone). The International Stratigraphic Lexicon (Smith, 1958) gives the type locality as 'road cuttings where the main Injune Road descends to Moolayember Creek north of Injune', but does not give the source of this information. A section has been measured in this area, and is nominated as the type section (Fig. 6).

The Moolayember Formation crops out in the Great Dividing, Carnarvon, Expedition, and Dawson Ranges. It generally forms gently rolling country with few strike ridges and no large hills, except in the rugged Expedition Range. It does not crop out in the Mundubbera Sheet area.

Lithology: In the type area the formation consists mainly of green-brown lithic sandstone interbedded with green-brown mudstone. The mudstone is generally

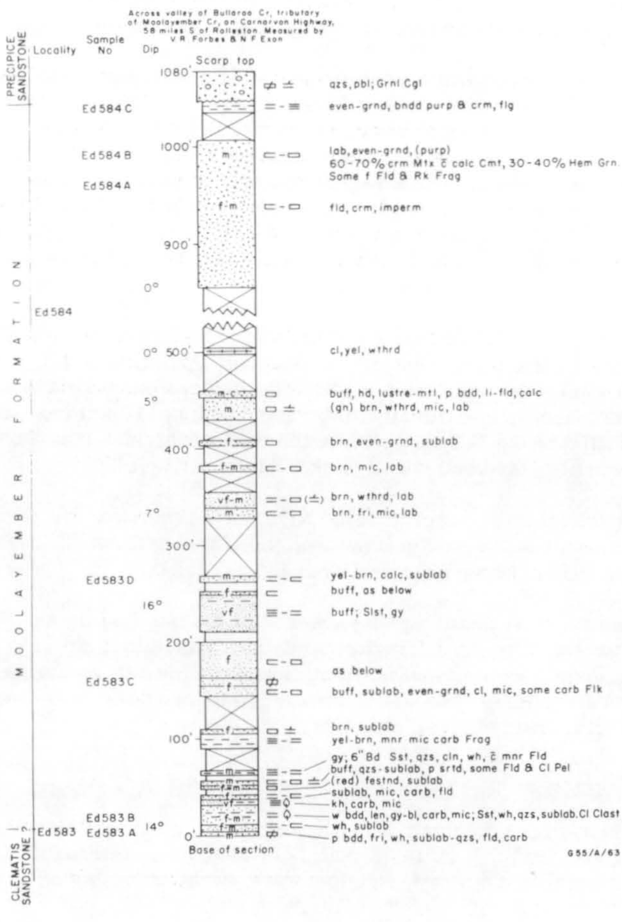

Fig. 6. Type section of the Moolayember Formation.

soft and massive, and commonly contains calcareous beds and concretionary nodules. The mudstone may contain carbonaceous plant debris, and in places it grades into carbonaceous shale. The sandstone in the type area is medium to coarse-grained and moderately well sorted; the sandstone commonly has a calcite cement which produces a mottled effect. Trough cross-stratification is common and small-scale slumping was observed in a few places. Although most of the arenites are lithic sandstone, there are some beds of lithic sublabile sandstone.

In the Expedition Range, the formation consists mainly of mudstone interbedded with lithic sandstone, carbonaceous shale, and rare conglomerate. As in the type area the sandstone is generally lithic and there are a few beds of lithic sublabile sandstone. In the conglomerate many of the pebbles consist of volcanic rocks.

In the Dawson Range the lithology is somewhat different. Mudstone, similar to that in the type area, is again predominant, but is interbedded with conglomerate and tuff as well as sandstone. The sandstone is generally lithic and contains a brown phyllosilicate, possibly biotite, which is also present in the matrix. Calcareous concretions are common; bands of pebbles of volcanic rocks are common in some beds, and mud pellets are common throughout. The sandstone at the base of the sequence is sublabile, and seems to grade downwards into the sublabile sandstone of the Clematis Sandstone.

In a few places in the Dawson Range a hard cherty rock, which commonly contains dark carbonaceous plant debris, crops out. This could be a siliceous tuff, and if so volcanoes were active while part of the formation was being deposited.

The interbedded conglomerate in the Dawson Range consists almost entirely of fine-grained volcanic rocks. Most of the phenoclasts are round to subround, and range from 1 to 10 cm in diameter; sphericity is moderate to high. The conglomerate crops out in beds up to 3 m thick.

Structure and Relationships: The Moolayember Formation, which rests conformably on the Clematis Sandstone, is folded into the Mimosa Syncline and the anticlinorium to the west. The maximum regional dip on the eastern side of the Mimosa Syncline is 20° west.

The Moolayember Formation is overlain unconformably by the Jurassic Precipice Sandstone.

Thickness: Dip measurements and the width of outcrop on the air-photographs indicate a thickness of at least 1350 m in the Dawson Range area, but the top is not exposed. Olgers et al. (1966) have estimated a total of 165 m in the Baralaba Sheet area, using the results of seismic surveys by United Geophysical Corp. (UGC, 1963).

The formation is 314 m thick in the type section, where the top is unconformably overlain by the Precipice Sandstone.

Age: On plant evidence the age of the formation is Triassic or Lower Jurassic (Appendix 3). A sample from the type area (T232), and one from Hungry Creek (T286) to the south, yielded Middle to Upper Triassic spores (Evans, 1964a). As the overlying Precipice Sandstone is Lower Jurassic (Evans, 1964c), the Moolayember Formation is probably restricted to the Triassic. It is therefore regarded as Middle to Upper Triassic.

Environment of Deposition: The abundance of plant material and lack of marine fossils suggest that the Moolayember Formation is mainly terrestrial. The abundance of conglomerate in the east and the presence of trough cross-bedded sandstone throughout the sequence point to a fluvial environment, although it is not impossible that some of the deposition took place in lakes. There are some indications, especially in the east, of contemporaneous vulcanism, and certainly the sediments in the east were largely derived from a volcanic terrain.

Exhumed Late Triassic Land Surface

A silicified late Triassic land surface (Fig. 7) is now exposed in many places where the overlying Jurassic sediments have been stripped off. Near Gyranda homestead in the Mundubbera Sheet area the altered sediments consist of white aphanitic chert. The chert forms a horizontal sheet, up to 9 m thick, on Permian and Triassic sediments dipping at about 20° to the west. Faint traces of bedding, parallel to the bedding in the underlying sediments, can be seen in the chert, and Permian and Triassic fossils have been found in places.

The silicification of the exhumed land surface decreases to the west, and the surface is not silicified in the Taroom and Baralaba Sheet areas.

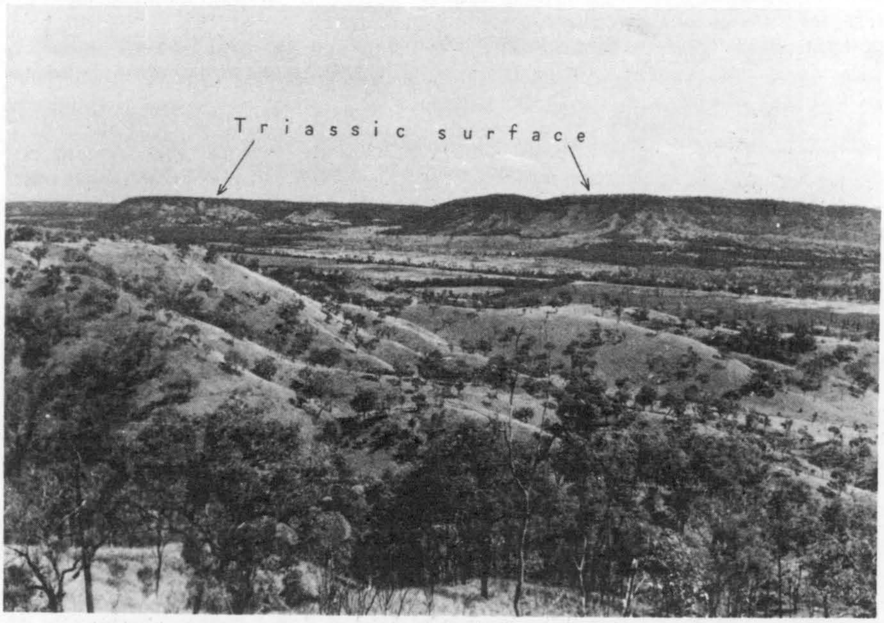

Fig. 7. Exhumed Triassic surface.

LOWER JURASSIC SEDIMENTS

A summary of Jurassic to Cainozoic stratigraphy is presented in Table 4.

Precipice Sandstone (Whitehouse, 1952)

The Precipice Sandstone is a widespread cliff-forming quartzose sandstone ranging from 30 to 150 m thick. It rests unconformably on Permian, Triassic, and older units, and is conformably overlain by the Evergreen Formation. The formation has been folded into a series of broad anticlines and synclines, but only minor faults and small intrusives have been noted.

Type Section: The type section was measured in a tributary of the Dawson River, 3 km east-southeast of Fairview homestead in the Taroom Sheet area (lat. 25°37'S, long. 148°59'E).

Distribution: The Precipice Sandstone has been eroded into spectacular gorges and ranges such as the Nathan Gorge in the Mundubbera Sheet area, the Isla Gorge and

TABLE 4: JURASSIC TO CAINOZOIC STRATIGRAPHY

Age	Formation (map symbol)	Lithology	Thickness in Outcrop (m)	Relationships	Fossils and Depositional Environment
CAINOZOIC	(Cza)	Alluvium	Up to 30(?)		
	(Cz)	Thick soil, sand, bouldery gravel	Up to 15(?)		
		Laterite, lateritic soil	Up to 15(?)	Developed on Jurassic, Cretaceous, and Tertiary units in places	
TERTIARY	(Ta)	Unconsolidated gravel, clay	Up to 25	Unconformable on Palaeozoic and Mesozoic units	Fluvial
	(Tb)	Olivine basalt, trachybasalt, minor pyroclastics and quartzose sandstone	15-240	Unconformable on Palaeozoic and Mesozoic units	Terrestrial
	Tabor Gabbro (Tt)	Olivine gabbro stocks and sill		Intrudes Hutton Sst	
LOWER CRETACEOUS	Doncaster Member (Wallumbilla Fm) (Kld)	Siltstone, shale, sublabile sandstone	60	Conformable on Bungil Fm and Hooray Sst	Marine shelly fossils in adjacent areas. Shallow marine

Age	Formation (map symbol)	Lithology	Thickness in Outcrop (m)	Relationships	Fossils and Depositional Environment
LOWER CRETACEOUS	Claravale Sandstone Member (Bungil Fm) (Klx)	White cross-bedded quartzose sandstone, siltstone, claystone	24-	Apparently conformable on Southlands Fm. Facies equivalent of upper part of Hooray Sst	Wood. Fluvial
JURASSIC to CRETACEOUS	Hooray Sandstone (J-Kh)	White cross-bedded quartzose to labile sandstone, some pebbly; siltstone and claystone	120±	Apparently conformable on Westbourne Fm. Facies equivalent of Bungil Fm, Southlands Fm, Gubberamunda Sst, and Mooga Sst	Wood. Fluvial
	Southlands Formation (J-Ks)	Siltstone, mudstone, quartzose to labile sandstone; some calcareous	120±	Conformable on Gubberamunda Sst. Facies equivalent within Hooray Sst	Wood and leaf fragments. Lacustrine, fluvial
JURASSIC	Gubberamunda Sandstone (Jug)	White cross-bedded quartzose and sublabile sandstone, minor siltstone	60-75	Apparently conformable on Westbourne Fm. Facies equivalent of lower part of Hooray Sst	Plants, fossil wood. Fluvial
	Westbourne Formation (Juw)	Siltstone, mudstone, fine cross-bedded quartzose sandstone	105-240	Conformable on Birkhead Fm and Adori Sst	Plants, spores, acritarchs. Lacustrine, deltaic

Age	Formation (map symbol)	Lithology	Thickness in Outcrop (m)	Relationships	Fossils and Depositional Environment
JURASSIC	Adori Sandstone (Ja)	White cross-bedded feldspathic to sublabile sandstone, some pebbly; minor siltstone and claystone	0-60	Apparently conformable on Birkhead Fm	Plants. Fluvial
	Springbok Sandstone (Js)	Cross-bedded labile sandstone; some siltstone, mudstone, and coal	0-45	Conformably overlies Birkhead Fm. Surat Basin equivalent of Adori Sst	Fluvial
	Birkhead Formation (Jmb)	Calcareous labile and sublabile sandstone, carbonaceous siltstone and mudstone, coal	150-270	Apparently conformable on Hutton Sst	Plants, spores, acritarchs. Paludal, minor lacustrine
	Hutton Sandstone (Jlh)	Feldspathic sublabile sandstone, siltstone, claystone	120-165	Conformable on Evergreen Fm	Small pelecypods, plants, spores. Fluvial or lacustrine
	Evergreen Formation (Jle)	Labile and sublabile sandstone, mudstone, siltstone, shale, coal	120-160	Conformable on Evergreen Fm	Plants, spores, pelecypods. Fluvial, lacustrine
	Westgrove Ironstone Member (Jlw)	Concretionary ironstone, oolitic in places; mudstone	9-24	Top of Evergreen Fm on W side of Mimosa Syncline	Plants, acritarchs. Shallow marine(?)

Age	Formation (map symbol)	Lithology	Thickness in Outcrop (m)	Relationships	Fossils and Depositional Environment
JURASSIC	Oolite Member (Jlo)	Oolitic or pelletal limonite, mudstone	6-9	Member within Evergreen Fm on E side of Mimosa Syncline	Plants, pelecypods, spores, acritarchs. Shallow marine(?)
	Boxvale Sandstone Member (Jlb)	Quartzose sandstone, minor siltstone, coal	9-45	Member within Evergreen Fm; overlain conformably by Oolite Member	Logs, stems. Deltaic, lacustrine(?)
	Precipice Sandstone (Jlp)	Pebbly quartzose sandstone, argillite, minor siltstone	30-150	Unconformable on Permian and Triassic units	Spores, plants, logs. Fluvial

Carnarvon Ranges in the Taroom Sheet area, and the Carnarvon Gorge (Fig. 8) and valley of the Maranoa River in the Eddystone Sheet area. It gives rise to a light porous sandy soil, supporting open eucalypt forest with poor grass or spinifex in the valleys, and low softwood scrub on the rocky tablelands. Both the upper and lower boundaries are marked by abrupt changes in topography. The high white cliffs at the base of the formation show up clearly on the air-photographs. The weathered Precipice Sandstone has a coarse-textured light-toned pattern on air-photographs (e.g. in the Mount Moffatt/Emu Bends area on the Eddystone Sheet). The Precipice Sandstone commonly forms plateaux, mesas, and buttes, cut by deep straight narrow gullies and gorges, many of which are controlled by joints. In places natural arches (Fig. 9) have been formed by differential erosion. The abrupt change from the plateaux and gorges of the Precipice Sandstone to the gently sloping topography of the Evergreen Formation is easily distinguished on the air-photographs. In the Taroom Sheet area, a thin or medium-bedded white argillite, which has a smooth white tone on the air-photographs, is present at the base of the Evergreen Formation.

Lithology: In the type section (Pl. 2, TA24), thick-bedded quartzose sandstone extends to the top of the cliffs, above which thin and medium-bedded sublabile and labile sandstone and mudstone of the Evergreen Formation became dominant. The boundary is gradational, but is taken above the last massive quartzose sandstone. In the Mundubbera Sheet area, the top of the formation includes some interbedded siltstone and argillite, but in the Taroom and Eddystone Sheet areas sandstone predominates throughout.

The sandstone is predominantly quartzose, though lithic sublabile sandstone occurs in places, generally near the top of the formation. It is generally poorly sorted and quartz-pebble bands are common. Very coarse sandstone and granule conglomerate are more common towards the base of the formation. Muscovite flakes and plant stem impressions are common, and red garnet has also been recognized. Authigenic pyrite is common; it forms rosettes up to 2 cm in diameter and nodules impregnated with pyrite up to 7 cm in diameter. Some of the pyrite nodules from near Fairview homestead (Taroom Sheet) are stained green when weathered.

The sandstone is generally thick-bedded and cross-stratified; the cross-stratification is generally planar, but both simple and trough cross-stratification have been observed. Sets range in thickness from a few centimetres to 3 m (Figs 10, 11). The orientation of the cross-beds is illustrated in Figure 12.

The finer-grained sediments towards the top of the formation, particularly in the Mundubbera Sheet area, include siltstone and argillite. The siltstone is generally white to yellowish brown, and laminated. The argillite is white, hard and flaggy, and commonly has minute plant impressions on bedding planes. Both are generally micaceous. Thin coal seams and interbeds of carbonaceous shale have been noted, especially in the Mundubbera Sheet area.

Relationships: The Precipice Sandstone rests unconformably on Permian and Triassic sediments, and is overlain conformably by the Evergreen Formation. The upper contact is gradational, but appears to mark a definite change in environment of deposition over a large area of the Surat Basin.

The formation is intruded by a few small basaltic dykes and plugs, and gabbroic intrusions (see Table 7).

Environment of Deposition: The lack of marine fossils and the abundance of plant impressions indicate a terrestrial environment. The coarse cross-stratification, particularly in the lower part of the formation, testifies to the presence of strong traction currents characteristic of river channels. The reduction in grainsize towards the top of the formation may indicate a reduction in velocity of the streams. To explain the great volume and extent of the Precipice Sandstone, Whitehouse (1952, p. 91) has

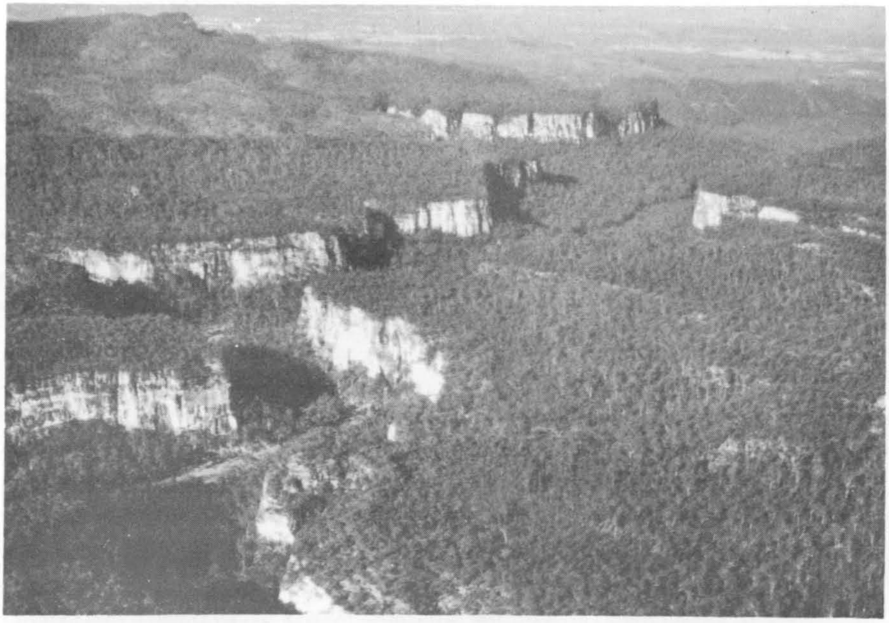

Fig. 8. Cliffs of Precipice Sandstone in Carnarvon Gorge, Eddystone Sheet area.

Fig. 9. Natural arch in Precipice Sandstone, 6½ km northwest of Mount Moffat homestead, Eddystone Sheet area.

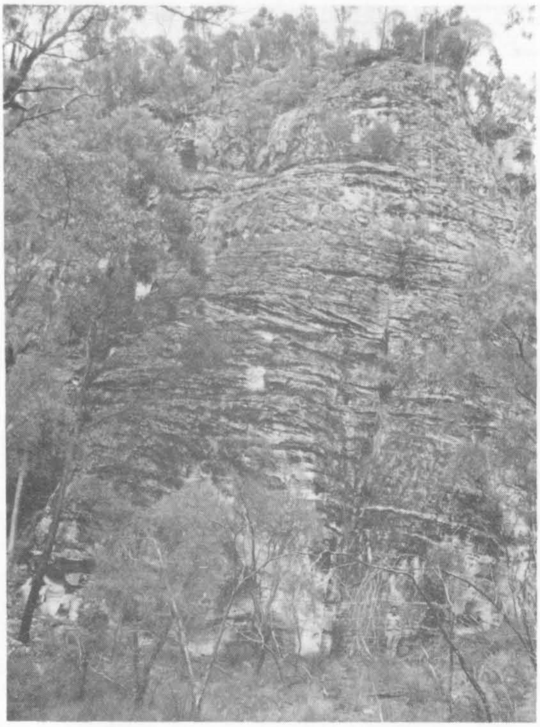

Fig. 10. Cross-stratification in the lower part of the Precipice Sandstone, Taroom Sheet area.

Fig. 11. Close-up view of cross-stratification commonly found in lower part of Precipice Sandstone, 9½ km south-southeast of Mopala homestead, Taroom Sheet area.

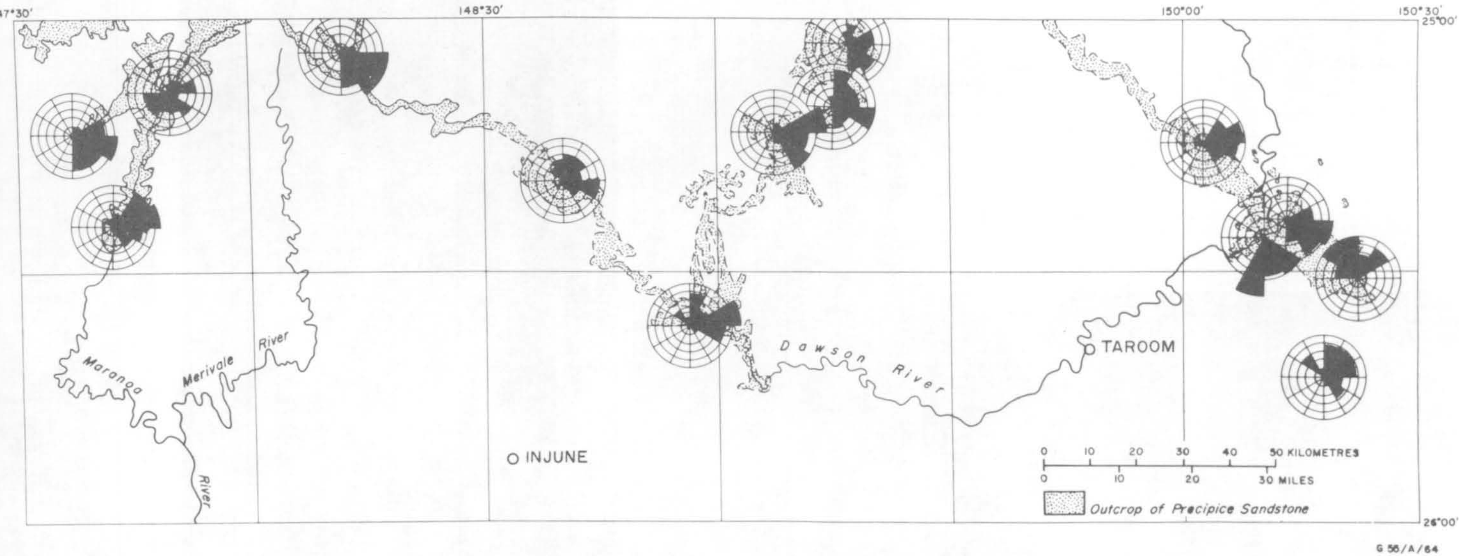

Fig. 12. Cross-bedding azimuths in the Precipice Sandstone.

suggested that the sands were deposited by streams in large basins, and that the finer-grained sediments were transported beyond the basins to the sea.

The well bedded fine-grained sediments and three seams of coal in the Precipice Sandstone were probably laid down in local lakes or swamps.

The orientation of the cross-beds indicates currents mainly from the west (Fig. 12). Orientation is less consistent in the Mundubbera Sheet area, probably because it is near the eastern limit of sedimentation.

Thickness: The thickness of the Precipice Sandstone ranges from 30 to almost 150 m. It is thinnest in the Mundubbera Sheet area, and thickens to the west, where it reaches 100 m at Nathan Gorge and 120 m in the Burunga No. 1 well. In the Taroom Sheet area it is about 75 m thick in the northeast corner, and thins to 45 m over the anticlinal axis southeast of the Arcadia Anticline. The formation thickens in the Eddystone Sheet area to about 90 m in the centre and east, and to almost 150 m in Warrong No. 1, in the north (Pl. 1).

Age: Evans (1964c) has reported Lower Jurassic spores in a 2-m bed of carbonaceous siltstone about 15 m above the base of the formation in Baffle Creek, 2.5 km northeast of Fairview homestead. The assemblage includes species of Classopollis, numerous bisaccate gymnosperm pollen grains, and a variety of pteridophyte microspores referable to Cyathidites, Baculatisporites, Lycopodiumsporites, Ischyosporites, Perotrilites, and several undescribed genera.

Evergreen Formation

The Evergreen Formation includes all the Lower Jurassic sediments between the Precipice Sandstone and Hutton Sandstone. Three members have been differentiated: the Boxvale Sandstone Member, Westgrove Ironstone Member, and an unnamed oolite member. The Boxvale Sandstone Member is essentially a quartzose sandstone; the others are beds of chamositic mudstone. The lower part of the Evergreen Formation was probably deposited in freshwater lakes, but there are indications of at least two brief marine incursions in the upper half.

Nomenclature: Whitehouse's (1952) term Evergreen Shale has been extended to include the Boxvale Sandstone of Reeves (1947) and two other members, because it has become clear that they are episodes in a dominantly argillaceous sequence. The entire sequence now included in the Evergreen Formation is illustrated in Plate 2.

Distribution and Topography: The Evergreen Formation crops out in a continuous arcuate belt across the area mapped. The Westgrove Ironstone Member crops out poorly, and is covered by rich dark soil and thick vegetation. The oolite member generally forms a small scarp, and weathers to good soil which supports thick vegetation. The Boxvale Sandstone Member crops out prominently and invariably forms one or more steep scarps. The rest of the formation is generally poorly exposed; it gives rise to dark heavy clay soils covered by thick vegetation.

A type section, from the base of the formation to the top of the Boxvale Sandstone Member, was measured 3 km east-southeast of Fairview homestead in the Taroom Sheet area. The upper part of the sequence was measured from cores and cuttings from Taroom BMR No. 46 and No. 54 (lat. 25°29'S, long. 148°40'E). A composite log is shown in Figure 13.

Lithology: The Evergreen Formation below the Boxvale Sandstone, or beneath the oolite member where the Boxvale Sandstone is missing, consists of a sequence of labile and sublabile sandstone, mudstone, and argillite, with minor siltstone, shale, and coal. Sandstone constitutes about half of the outcrops, but the other sediments crop out poorly. The sandstone is labile or sublabile, and is generally fine to medium-grained;

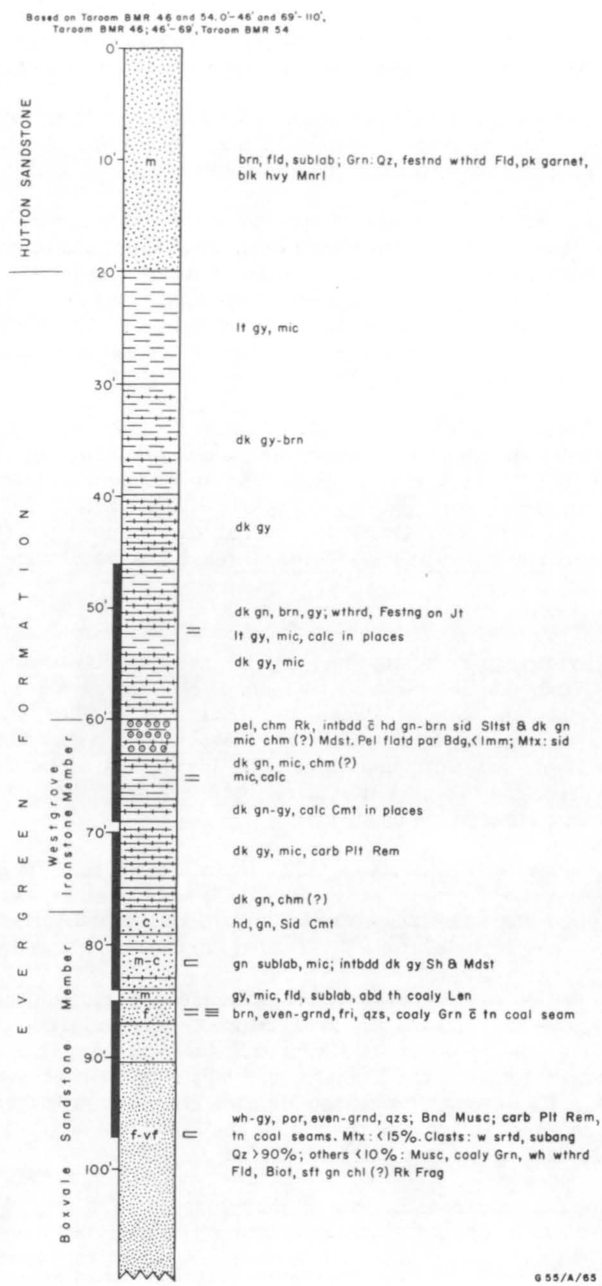

Fig. 13. Composite section of upper part of Evergreen Formation.

the beds are generally lenticular. It appears to be more labile towards the top and more quartzose at the base, but the proportion of quartz grains is rarely more than 60 percent. The sandstone is generally light grey, flaggy, and micaceous, and is probably feldspathic near the base of the formation; it becomes greenish and massive with the increase in lithic fragments higher in the section. Beds containing coaly plant fragments and thin streaks of coal are common. A coarse pebbly sublabile sandstone near Mount Misery in the Mundubbera Sheet area contains quartz grains, lithic fragments, and pebbles of fossil wood, chert, quartzite, and flint. The sandstone beds range from 60 cm to 2.5 m in thickness; the thinner beds are more common near the base. The sandstone generally has an argillaceous matrix and is impermeable. Calcareous and ferruginous cements are common and lustre mottling has been noted. Ripple marks and small-scale cross-stratification are present, and fossil wood and stem impressions are common in the lower half of the formation.

The finer-grained sediments in the section below the Boxvale Sandstone are mudstone and argillite. At the base of the formation the argillite is hard, dense, white, flaggy, micaceous, and medium-bedded. Interbeds of argillite are also common in the fine quartzose sandstone at the top of the formation. The argillite is commonly iron-stained along joints, particularly in the Mundubbera Sheet area. The mudstone is generally light green or khaki, and in places has a calcareous cement. A hard blue-grey massive sandstone with coaly plant fossils commonly occurs just below the oolite member in the Cockatoo Creek area (Mundubbera Sheet).

In the Eddystone Sheet area, the Boxvale Sandstone Member consists of upper and lower scarp-forming sandstones separated by a persistent poorly exposed soft sequence. The softer sequence includes thinly bedded siltstone, fine sublabile and quartzose sandstone, coal, and bedded ironstone. The bedded ironstone may be an altered chamositic sediment, similar to some of the ironstone in the Westgrove Ironstone Member, but no pelletal or oolitic structures have been noted. Some dark green labile sandstone is associated with the ironstone, particularly near Springvale in the Eddystone Sheet area, but chamosite has not been identified. In the Taroom Sheet area, where the threefold subdivision is not well marked, the member is thinner and eventually lenses out towards the centre of the Mimosa Syncline.

The member consists of two distinct types of sandstone. The first comprises thin ripple-marked beds of white very fine even-grained well sorted porous quartzose sandstone with abundant accessory zircon, tourmaline, and iron oxides in places. The grains are generally angular and are commonly oriented parallel to the bedding. The sandstone is generally porous, but in places quartz overgrowths are common and the rock is more resistant to weathering. Muscovite flakes are commonly concentrated in layers which impart a flaggy structure to the rock. Worm tubes are common. The sandstone contains interbeds of white or grey micaceous siltstone. The second type of sandstone is thickly bedded, poorly sorted, medium to coarse-grained, cross-bedded, and quartzose, and in places has an argillaceous matrix.

Both types of sandstone occur throughout the member, but the first type is common in the upper and the second in the lower part.

The Westgrove Ironstone Member (new name) consists predominantly of chamositic mudstone with a pelletal or oolitic structure and sideritic cement. In outcrop, the chamosite is oxidized to concretionary and pelletal limonite and hematite. The only fresh chamositic rock seen was in the cores from Taroom BMR No. 46 and No. 54*, and in the cuttings from Eddystone BMR No. 53. The chamosite occurs as soft waxy translucent dark brown pellets, most of which are less than 1 mm in diameter

*The sequence in BMR 46 and 54 is designated as the type section, for lack of good outcrop. (See Pl. 2 and Fig. 13).

and flattened parallel to the bedding. The pellets are set in a matrix of sideritic mudstone. Some of the pellets are partly or wholly altered to soft white kaolin(?). Beds of dark green micaceous chamositic(?) mudstone and hard brownish grey siltstone with a sideritic cement are interspersed throughout the member. The interval from 1060 to 1080 feet (323.1-329.2 m) in the Glentulloch No. 1 well contains pellets of chamosite, and crystals and irregular masses of siderite, in a mudstone with abundant sideritic cement. The chamosite pellets are generally flattened. It is not known whether the mudstone itself is chamositic. A partial analysis of the oolitic limonite from Expedition Creek in the Taroom Sheet area revealed a phosphorus content of 1.51 percent. This suggests that vivianite or collophane may be present. On exposure, the member weathers easily and the pelletal structure is commonly destroyed by oxidation. Most of the outcrops are covered by dark red-brown soil with concretionary limonite boulders in which a few relict pellets can be seen.

The interbedded sediments include mudstone, siltstone, and minor sandstone. The mudstone is generally greenish or purplish, commonly calcareous (or sideritic) and micaceous, and in places lustre-mottled. The siltstone is grey to green-brown and generally micaceous and calcareous. A dark green sandstone, consisting largely of chamositic(?) grains and some clear quartz, and very little matrix, is not uncommon.

Jointing is common. The finer calcareous sediments are commonly replaced along joint planes by iron oxides, and the rock grades into a concretionary ironstone. The bedding planes are gently undulating. Fossil log impressions up to 1.5 m long, and ferruginized logs, are common.

The oolite member near the top of the Evergreen Formation is widely distributed. It is generally less than 9 m thick, and consists of an oolitic or pelletal chamositic rock which weathers to limonitic ironstone. It is probably equivalent to the Westgrove Ironstone Member in the Mundubbera Sheet area and the upper part of the Boxvale Sandstone Member in the Eddystone Sheet area. In outcrop the oolite ranges from a homogeneous aggregate of tightly packed pinhead sized spherical limonite ooliths to a fine-grained brown ferruginous pelletal sandstone. There is generally a sharp contact between the pelletal and oolitic rocks and the interbedded siltstone or mudstone.

A bed of massive oolite, at least 1.25 m thick, crops out in the scarps bounding Pigeon Creek, in the Mundubbera Sheet area. Urquhart (1962) reported a bed of oolite over 3 m thick in this area. Several bands of oolite, ranging from a few centimetres to 1 m thick, are generally present. The limonitic oolite is yellowish brown in outcrop, and tends to split the slabs along the bedding planes. The ooliths are generally spherical, and about 0.5 mm in diameter. Many of them consist of a dark brown spherical shell filled with light brown earthy limonite. Some ferruginous silty matrix is generally present in the oolite. Weathering and solution have produced thin veins and layers of dark hard limonite.

The chief rock type associated with the oolite in outcrop is a heavy hard red and yellow banded ironstone, which was probably formed by ferruginization of a fine-grained sedimentary rock.

Most of the sediments interbedded with the oolitic and concretionary ironstone are ironstained. The sandstone is generally thin-bedded and sublabile, and the mudstone ranges from dark purple and structureless, or chocolate and ferruginous, to a grey or white slightly fissile rock. Urquhart (1962) reported 1.5 m of 'massive structureless, slightly micaceous silty ferruginous tuff (?), which is talcy to the touch', in the log of a drill hole about 3 km northeast of Cockatoo homestead. No tuffaceous rocks have been noted in outcrop.

The beds immediately below the oolite member in the Cockatoo Creek area include yellow and grey shale, yellow feldspathic sandstone, and white quartzose sandstone, which are generally underlain by massive blue-grey mudstone with coaly plant fossils.

The upper part of the Evergreen Formation seldom crops out, and in the Eddystone and Taroom Sheet areas is so thin and poorly exposed that it was not separated from the Westgrove Ironstone Member on the map; the sediments include greenish and purplish calcareous mudstone and mottled siltstone. In the Mundubbera Sheet area the sequence consists of yellow mudstone and siltstone and poorly sorted sublabile sandstone with a calcareous cement and some fossil logs.

Structure: The dip of the Evergreen formation is generally very low; but dips of up to 10° have been recorded in small local 'rolls'.

Relationships: The Evergreen Formation rests conformably on the Precipice Sandstone and overlaps on to the granodiorite basement in the Auburn Range in the Mundubbera Sheet area. In the same area, near Kilbeggan homestead, the lower part of the formation is overlapped by the oolite member.

The formation is overlain conformably by the Hutton Sandstone.

The Westgrove Ironstone Member and oolite member are lithologically similar. They may be equivalent, but in the west it is possible that the oolite member is represented by the ironstone horizon in the Boxvale Sandstone. In an effort to resolve this problem Bastian (1965c) made a detailed petrographic study of cores and cuttings from the Glentulloch No. 1, Rosewood No. 1, Kooringa No. 1, Meeleebee No. 1, Wandoan No. 1, and Burunga No. 1 wells. The Westgrove Ironstone Member was recognized above the Boxvale Sandstone in Glentulloch No. 1, Rosewood No. 1, Kooringa No. 1, and Meeleebee No. 1. The Boxvale Sandstone Member thins to 6 m in Rosewood No. 1, and is very thin in Kooringa No. 1. The typical well sorted fine-grained pure quartzose sandstone, with a characteristic sugary appearance of the Boxvale Sandstone Member, was not found in other wells to the east. It appears therefore that the member has either lensed out, or changed character.

In Wandoan No. 1, two pelletal beds were noted by Bastian (1965c) - a 3-m upper bed, and a 12-m lower bed. Both beds are within the interval 2750 to 2840 feet (838.2-865.6 m). Electric log correlations suggest that the upper bed is equivalent to the Westgrove Ironstone Member to the west. Only one pelletal bed is present in Burunga No. 1 on the edge of the Mundubbera Sheet area; this seems to be equivalent to the lower pelletal bed in Wandoan No. 1. Thus the oolite member in outcrop in the Mundubbera Sheet area may be equivalent to the lower pelletal beds in Wandoan No. 1. If the Westgrove Ironstone Member is equivalent to the upper pelletal bed in Wandoan No. 1, then the oolite member is older than the Westgrove Ironstone Member and probably equivalent to the ironstones of the soft sequence in the middle of the Boxvale Sandstone Member in the Eddystone Sheet area.

Deposition of the oolite member in the Mundubbera Sheet area may have begun with the first marine incursion in middle Boxvale Sandstone time, and continued until deposition of the Westgrove Ironstone Member ceased.

It can be correlated with the Westgrove Ironstone Member or the soft sequence near the middle of the Boxvale Sandstone Member in the Eddystone Sheet area, or both. The thickness of oolitic rock in the oolite member, and the occurrence of a number of separate oolitic horizons, suggest that the third correlation is most likely.

Environment of Deposition: The lower part of the Evergreen Formation was probably laid down in a lake or swamp: plant remains are abundant and well preserved, and small bivalves of probable freshwater origin (Dr D.F. McMichael, Aust. Mus., pers.

comm.) have been collected from the unit near Cockatoo Creek (T653a, T673, T766).

There is no field evidence of a break in sedimentation at the base of the Boxvale Sandstone Member. The coarse cross-bedded poorly sorted sandstone is probably fluvial or deltaic, and the fine well sorted ripple-marked sandstone was probably laid down in a shallow lake where currents or waves were active.

The thinly bedded fine sediments in the middle of the Boxvale Sandstone Member in the Eddystone Sheet area represent a change to still-water deposition, possibly brought about by deepening of the lakes. The presence of ironstones, which are probably chamositic, also indicates a change to quiet-water deposition. The alternating regularly bedded shale and irregularly bedded lenses of sandstone and siltstone towards the top of the soft sequence suggest intermittent turbulence in gradually shallowing water.

The marked grain orientation, good primary porosity, and concentrations of heavy minerals in the well sorted sandstone in the upper part of the Boxvale Sandstone Member indicate reworking in a littoral zone.

The chamositic ironstone members seem to have been deposited on the bottom of a moderately shallow marine basin, in a reducing environment, remote from strong current action, but subjected to gentle wave or tidal action. A source area of low relief with marked variation in rainfall seems most likely.

Most of the evidence for this lies with the interpretation of the presence of chamosite. Chamosite is a member of the chlorite family with the approximate composition $4FeO.Al_2O_3.3SiO_2.3H_2O$; magnesium oxide may also be present. Hallimond (1925) has shown that chamosite is precipitated, probably as a gel, where the product of the ferrous and aluminosilicic acid ion concentration exceeds the solubility product of chamosite, and that the concentration of the aluminosilicic ion is generally fixed by the almost universal presence of clays, which are progressively transformed into chamosite when the concentration of ferrous ion reaches the required limit. The fact that the iron is present in the ferrous state in both the chamosite and associated siderite suggests a reducing environment, and the presence of disseminated pyrite in one of the oolitic ironstones in the Mundubbera Sheet area is regarded as confirmatory evidence. Hallimond (1925, p. 42) concluded that 'chamositic mudstones are generally, if not invariably, marine', and suggested that the return to deposition of non-chamositic sediments corresponds to the transition from marine to estuarine or freshwater environment. Sheppard & Hunter (1960) in a study of Devonian chamositic oolites concluded that the environment was marine, and slightly reducing. Teodorovich (1961) noted that chamosite forms under reducing conditions in a littoral or shallow water environment. However, he also noted that it is found in the lower parts of present-day peat deposits, with beds of lacustrine-paludal calcite. There are no coaly seams associated with the ironstone in the area studied.

Conclusive fossil indicators of depositional environment are lacking. Broken plant stems and fossil logs are common, but no leaf impressions have been found. One small indeterminate pelecypod was collected. However, the occurrence of acritarchs in the upper part of the Evergreen Formation implies a saline rather than a freshwater environment.

The pelletal and oolitic structures suggest wave or current action at moderate depth, probably just above wave base. A feature of the oolite in the Cockatoo Creek area is the high degree of sphericity of the ooliths, and the uniform size grading.

The iron content of the chamosite was probably derived from a land source, and the shale and sandstone interbedded with the chamositic sediments indicate that some detrital material was carried into the basin. The alternation of clastic sedimentation with chemical precipitation probably reflects variations in rainfall and supply of terrigenous sediment.

The abrupt change in environment during the deposition of the Evergreen Formation is evidenced by the change from the turbulent water in which the Boxvale Sandstone Member was laid down to the relatively quiet conditions suggested by the overlying Westgrove Ironstone Member. This change suggests a moderate but abrupt deepening of the water which would shift the agitation farther from the centre of the basin and allow quiet-water deposition above the well sorted sandstone. The change in environment of deposition at the base of the oolite member in the Mundubbera Sheet area seems to have been just as abrupt as that at the base of the Westgrove Ironstone Member.

Thickness: The thickness of the Evergreen Formation ranges from 120 m in the northern part of the Eddystone Sheet to 145 m in the type area in the western part of the Taroom Sheet, and reaches a maximum of about 170 m in the Mundubbera and eastern part of the Taroom Sheet areas (see Pl. 2).

The Boxvale Sandstone Member has a maximum thickness of 75 to 90 m in the Binalong-Warrong area in the northern part of the Eddystone Sheet area, near the axis of the Maranoa Anticline. It has a minimun observed thickness of 9 m near Yebna homestead in the central part of the Taroom Sheet area; it lenses out towards the axis of the Mimosa Syncline. The member has not been recognized in the Mundubbera Sheet area. In general, the member appears to be thinner in synclines than elsewhere.

In the Taroom Sheet area the maximum thickness is 39 to 42 m between Mount Hutton homestead in the southwest and Reedy Creek homestead in the north. To the southeast (towards the axis of the Mimosa Syncline) the thickness decreases to about 20 m near Kurrajong homestead and near Burnley, and to 9 m at Yebna farther southeast. The thickness also decreases to the northwest; it is 65 feet (19.8 m) thick in Taroom BMR No. 46, and only 15 m thick near Boxvale homestead.

In the Eddystone Sheet area, the Boxvale Sandstone Member is about 35 m thick in the Westgrove Anticline in the Sardine Creek area, and about 48 m thick in the Serocold Anticline, in the Springvale homestead area. The greatest observed thickness was 75 to 90 m in the Binalong-Warrong area, near the axis of the Maranoa Anticline. The member thins southwards along this anticlinal axis, to 60 to 72 m in the Mount Owen/Darkwater area. The thickness ranges from 27 to 12 m in the wells in the axial region of the Merivale Syncline near Mount Hutton.

The observed thickness of the Westgrove Ironstone Member ranges from about 1 to 9 m. It thins from south to north. The greatest thicknesses are near the OK and Hutton Park homesteads in the Taroom Sheet area, and the Darkwater and Redbank homesteads in the Eddystone Sheet area. The member is probably less than 1.5 m thick near Mount Tabor in the Eddystone Sheet area and has not been recognized in the axial part of the Mimosa Syncline in the Taroom Sheet area.

The thickness of the oolite member, as estimated by barometric levelling, and from Urquhart's (1962) drill logs in the Cockatoo Creek area and water-bore logs in other areas, is less than 12 m, and generally between 6 and 9 m. It has not been recognized in the axial part of the Mimosa Syncline between Currajong and Karrinya homesteads. In this area, the oolite member is either very thin and covered by the blanket of sand weathered from the Hutton Sandstone, or it is absent.

Macropalaeontology: Collections of plant fossils (see Appendix 3) and pelecypods, and one indeterminate vertebrate bone fragment from locality T620, have been made from the Evergreen Formation in the Mundubbera Sheet area. The stratigraphic position of the collections is shown in Figure 14. The identification of Permian Merismopteria sp. from Cockatoo Creek, reported by Laing (in Hill & Denmead, 1960), is no longer sustained (Prof. Dorothy Hill, pers. comm.).

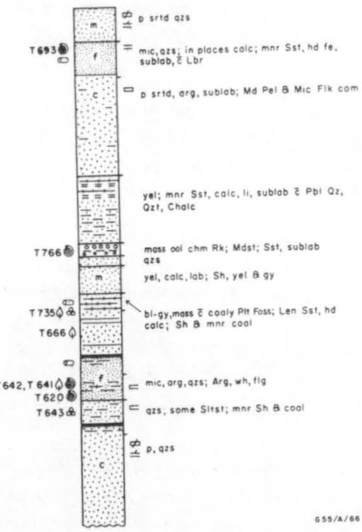

Fig. 14. Stratigraphic position of fossil collections in the Cockatoo Creek/ Bungabin Creek area.

The macrofossils found in the oolite member include indeterminate plant stems, wood impressions, and small indeterminate pelecypods (T766).

The pelecypods are not sufficiently well preserved to be certain as to their identity and ecology, but Dr D.F. McMichael (pers. comm.) has indicated that three kinds seem to be present: one looks like the freshwater mussel Mesohyridella ipsviciensis; one like a species of Unionella; and the third like a mytiloid genus. The first two suggest freshwater deposits, and the third a marine or estuarine environment.

Palynology: Evans (1964a) refers the sequence below the oolite member in the Mundubbera Sheet area to his unit J1, and the oolite member and shaly sequence above it to unit J2. He has identified the following species in two samples (T653, T735) from the basal of the Evergreen Formation:

T653. Rocky Creek, Mundubbera Sheet (lat. 25°43'S, long. 150°17'E): Cyathidites cf. C. minor Couper, 'Apiculati sp. nov.', Laricoidites sp., Bisaccatae spp. undiff., Classopollis sp. (very common).

T735. 1 km south of Dawsonvale homestead, Mundubbera Sheet (lat. 25°33'S, long. 150°13'E). An abundant but somewhat oxidized yield of: Stereisporites sp., Lycopodiumsporites spp., Perotrilites cf. P. tenuis De Jersey, Bisaccatae spp. undiff., Classopollis sp. (very common).

Samples of the oolite member from Mundubbera BMR No. 29 yielded spores of Evans' unit J2. Evans considered that the oolite member coincides with the boundary between units J1 and J2. He also noted the association of acritarchs with this pelletal member.

Age: Plants found in the Evergreen Formation are Jurassic (see Appendix 3) and the spores indicate a Lower Jurassic age (De Jersey & Paten, 1964).

Hutton Sandstone

The Hutton Sandstone consists mainly of a thick sequence of sandstone which conformably overlies the Evergreen Formation.

Nomenclature, Type Area, and Lithology: The name Hutton Sandstone was first used by Reeves (1947, p. 1346) for the top member of the Bundamba Series about 40 km northwest of Injune (lat. 25°32'S, long. 148°29'E), in the Eddystone Sheet area. Whitehouse (1954) considered this formation in the Roma district to be equivalent to the Marburg Formation of the Ipswich district. However, since basalt and other cover preclude tracing the Hutton Sandstone into the type area of the Marburg Formation in the Moreton Basin, it is thought advisable to retain the name Hutton Sandstone for the present.

No type section could be measured in the area nominated by Reeves for lack of outcrop, and a new type section (Pl. 2, loc. TA25) was measured near Hutton Creek 19 km east-northeast of Injune in the Taroom Sheet area (lat. 25°47'S, long. 148°46'E).

The Hutton Sandstone crops out in a broad continuous arcuate belt of sandy country stretching from east to west across the area mapped.

The sandstone is generally friable and weathers to sandy soil. Massive outcrops are generally smooth-sided and rounded; vertical cliffs are rare. The abundant but poor sandy soil supports some grass and open forest of pine, lancewood, and wattle. On air-photographs the Hutton Sandstone can be distinguished from the Precipice Sandstone by its darker tone, from the Boxvale Sandstone and ironstone members of Evergreen Formation by its rounded hills and sparse forest, and from the Birkhead Formation also by the density of vegetation.

The Hutton Sandstone consists mainly of sandstone, with some siltstone and mudstone in places, and rare pebble conglomerate. The medium-grained poorly sorted feldspathic(?) sublabile sandstone with an argillaceous matrix at the base of the formation generally grades into fine-grained well sorted quartzose sandstone at the top. Mud galls occur throughout, but appear to be more common near the base. The quartz grains are generally angular, and the matrix is commonly argillaceous. The sandstone is generally poorly cemented and friable, but ferruginous and calcareous cements have been noted in places.

The sandstone weathers easily and is poorly exposed. One of the best exposures is in a small rocky butte just north of Mount Moffatt in the northern part of the Eddystone Sheet area, where the sediments may have been slightly indurated by basalt. Between 120 and 150 m of pinkish white medium-grained thick-bedded feldspathic sublabile sandstone belonging to the lower part of the Hutton Sandstone is exposed. Beds containing granule and pebble bands, white mud clasts up to 15 cm across, small manganiferous and ferruginous nodules, and bands of heavy minerals were noted in this exposure. Both large-scale and small-scale cross-bedding are present.

The 54-m section of the basal part of the Hutton Sandstone penetrated in Eddystone BMR No. 51 consists mainly of grey medium-grained even-grained soft feldspathic sublabile sandstone. The accessory minerals include muscovite, micaceous hematite, grains of coal, pink garnet, and black minerals. The rock commonly has an argillaceous matrix and is generally impermeable. It weathers to a brown earth. The lower part of the Hutton Sandstone seems to be finer and more quartzose in the Injune area than in the rest of the area mapped.

The upper half of the Hutton Sandstone is more uniform. The sequence consists predominantly of light brown or white fine and even- grained porous friable generally thick-bedded structureless quartzose sandstone, with an argillaceous matrix in places, and subordinate poorly sorted sublabile sandstone, hard yellow calcareous sandstone, and quartz-pebble bands. The fine-grained quartzose sandstone commonly occurs as thick uniform beds, which are up to 25 m thick in the Gwambagwine and Pony Hills area (Taroom Sheet). They are generally structureless, but some minor current-bedding has been seen.

Thinly bedded sediments are common at the top of the formation. At the road crossing at Highland Plains Creek (Taroom Sheet) thinly bedded ripple-marked fine-grained quartzose sandstone and interbedded yellow mudstone are exposed. Thin-bedded sediments are also exposed in the road crossing at Bungabin Creek, near Bungabin homestead (Mundubbera Sheet). They include fine-grained yellow micaceous quartzose sandstone interbedded with some siltstone, rare hard calcareous quartzose sandstone, and one thin bed of hard ferruginous partly concretionary labile sandstone. The ferruginous bed contains a few plant stems and small pelecypods (collection T693). The thin-bedded sequence in this area is overlain by thick-bedded poorly sorted strongly cross-bedded coarse quartzose sandstone.

Thin sheets of mottled laterite rubble are found on the Hutton Sandstone in a few areas. The basalt in the northern part of the Taroom Sheet area has silicified the Hutton Sandstone and in one place it has been converted into grey silcrete.

The Hutton Sandstone lies conformably on the Evergreen Formation, and the Birkhead Formation is generally conformable over it. However, the presence of a basal conglomerate in places in the Birkhead Formation, and the marked lithological differences between the two formations, suggest local disconformity.

Environment of Deposition: Little is known of the environment of deposition of the Hutton Sandstone. No determinable fossils have been found. The groundwater in the lower part of the formation is commonly brackish or salty, with a high content of sodium chloride, calcium sulphate, and sodium carbonate. Salt encrustations have been noted on outcrops in creeks around Bentley Park homestead in the Mundubbera Sheet area and around Warndoo homestead in the Taroom Sheet area. Thus the lower part of the formation, at least, may have been deposited in brackish water.

The thickness and poor sorting of the sediments in the lower part of the formation suggest rapid deposition, little reworking, and an abundant supply of terrigenous sediment. These characteristics could be the result of slightly accelerated subsidence, with some uplift of the source area. The better sorting of the sandstone near the top of the formation may indicate deposition in shallower water, and more reworking of the sediment. Minor cross-bedding indicates that parts of the formation were probably deposited by streams. Allen & Houston (1964) reported a change from the abundance of fragments of granitic and metamorphic rocks in the sandstones of the Evergreen Formation to the predominance of fragments of volcanic rocks in the Hutton Sandstone.

Thickness: The Hutton Sandstone is 120 to 225 m thick. It is generally thicker in synclines than in the anticlines. In the Mundubbera Sheet it is about 135 m in the Cockatoo Creek area, thickening toward the Mimosa Syncline, and about 225 m in Burunga No. 1. In the Taroom Sheet it thins to west of the Mimosa Syncline to an estimated 165 m at Pony Hills, and to a measured 120 m near the South Hutton Dome. In the Eddystone Sheet, the thickness is 180 to 195 m in the axial region of the Merivale Syncline near Mount Hutton. Towards the Maranoa Anticline it thins to 147 m in Tooloombilla No. 1 in the south, and to an estimated 135 to 150 m cropping out near Mount Moffat in the north. No reliable estimate of the thickness west of the Maranoa Anticline can be made, but the decreasing width of outcrop suggests gradual thinning towards the northwest.

Fossils and Age: Some small indeterminate pelecypods were seen near the top of the formation in an outcrop in Bungabin Creek in the Mundubbera Sheet area (lat. 25°54'S, long. 150°08'E); plant stems and logs have also been recorded.

The palynological evidence (De Jersey &Paten, 1964) indicates that the formation is mainly Lower Jurassic and that it probably extends into the Middle Jurassic.

MIDDLE JURASSIC TO LOWER CRETACEOUS SEDIMENTS

The present survey, and surveys of the Mitchell Sheet (Exon, Galloway, & Casey, 1966a) and the Tambo and Augathella Sheets (Exon, Galloway, Casey, & Kirkegaard, 1966b), supported by palynological studies (Evans, 1966a,b) and gamma-ray logging, have led to changes in generally accepted correlations in the Middle and Upper Jurassic and Lower Cretaceous sequences of the Surat and Eromanga Basins (Exon, 1966). Several units wedge out on or near the Nebine Ridge (Maranoa Anticline). The correlation across the Nebine Ridge is shown in Table 5 and Figure 15. The Gubberamunda Sandstone, Orallo Formation, and the lower part of the Bungil Formation are represented to the west of the Hooray Sandstone. The underlying Injune Creek Group is subdivided into three units in the west: the Birkhead Formation, the Adori Sandstone, and the Westbourne Formation. In the east the Springbok Sandstone occupies the position of the Adori Sandstone.

Two further new names are presented here: the Southlands Formation, between the Maranoa and Alicker Anticlines (easternmost part of Mitchell Sheet area), is equivalent to the Mooga Sandstone and Kingull Members of the Bungil Formation, plus the Orallo Formation, in the Roma area; the Claravale Sandstone Member of the Bungil Formation is a thin sequence above the Southlands Formation in the Merivale Syncline.

Largely on palynological grounds (e.g. Evans, 1966b), the Birkhead Formation is regarded as Middle Jurassic, the Adori Sandstone and Springbok Sandstone as Middle or Upper Jurassic, the Westbourne Formation and Gubberamunda Sandstone as Upper Jurassic, the Southlands Formation and Hooray Sandstone as Upper Jurassic to Lower Cretaceous, and the Bungil Formation as Lower Cretaceous.

Injune Creek Group (Exon, 1966)

Exon (1966) divided the Injune Creek Group in the west into three formations: the Birkhead Formation, Adori Sandstone, and Westbourne Formation.

The complete sequence crops out in the Eddystone Sheet area, but only the Birkhead Formation is present in the Taroom and Mundubbera Sheet areas. In the west the Birkhead Formation is overlain by the Adori Sandstone, which is, in turn, overlain by the Westbourne Formation. Near Mount Elliott in the central-southern part of the Eddystone Sheet area, the Adori Sandstone pinches out, and farther east the Westbourne Formation directly overlies the Springbok Sandstone.

TABLE 5: NOMENCLATURE AND CORRELATES - POST-HUTTON SANDSTONE

<table>
<tr><th colspan="2">Eddystone & Mitchell Sheets</th><th colspan="3">Roma & Taroom Sheets</th><th colspan="2">Company Nomenclature
(e.g. Blyth Creek No. 1)</th></tr>
<tr><td colspan="5">Doncaster Member</td><td colspan="2">Roma Formation</td></tr>
<tr><td rowspan="6">Hooray Sandstone</td><td colspan="3">Minmi Member</td><td rowspan="3">Bungil Formation</td><td rowspan="3">Transition Member</td><td rowspan="6">Blythesdale Formation</td></tr>
<tr><td colspan="3">Nullawurt Sandstone Member</td></tr>
<tr><td>Claravale Sandstone Member</td><td colspan="2">Kingull Member</td></tr>
<tr><td rowspan="2">Southlands Formation</td><td colspan="3">Mooga Sandstone</td><td>Mooga Member</td></tr>
<tr><td colspan="3">Orallo Formation</td><td>Fossil Wood Member</td></tr>
<tr><td colspan="4">Gubberamunda Sandstone</td><td>Gubberamunda Member</td></tr>
<tr><td rowspan="3">Injune Creek Group</td><td colspan="2">Westbourne Formation</td><td colspan="2" rowspan="3">Undivided Injune Creek Group</td><td colspan="2" rowspan="3">Injune Creek Beds</td></tr>
<tr><td>Adori Sandstone</td><td>Springbok Sandstone</td></tr>
<tr><td colspan="2">Birkhead Formation</td></tr>
<tr><td colspan="5">Hutton Sandstone</td><td colspan="2">Hutton Sandstone</td></tr>
</table>

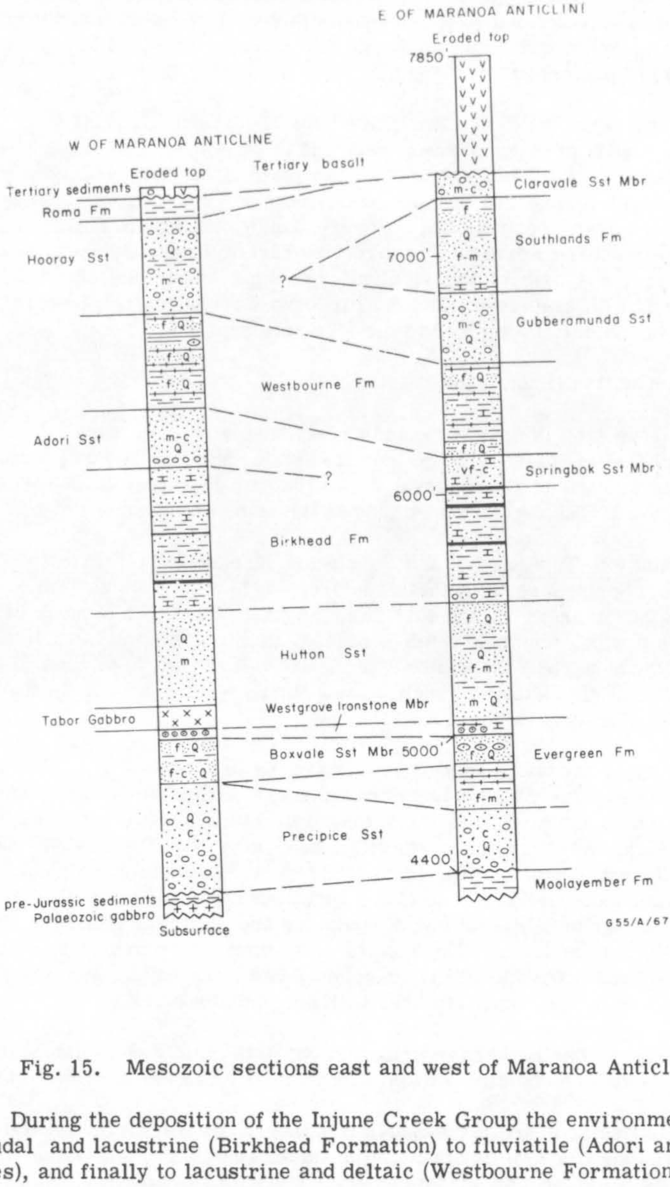

Fig. 15. Mesozoic sections east and west of Maranoa Anticline.

During the deposition of the Injune Creek Group the environment changed from paludal and lacustrine (Birkhead Formation) to fluviatile (Adori and Springbok Sandstones), and finally to lacustrine and deltaic (Westbourne Formation).

In the east a disconformity may be present at the base of the Westbourne Formation. No macrofossils were collected, but previous palaeobotanical determinations by Wilcox (1926) and Whitehouse (1954) indicate a Jurassic age. Palynological evidence suggests that the age of the group ranges from Middle to Upper Jurassic (Evans, 1966b).

Nomenclature: The name Injune Creek Beds was first used by Jensen (1921 p. 92). He appears to have used it mostly for the Lower or Calcareous Walloon Stage of his Walloon Series. The name has since been applied by many geologists to the whole of Jensen's Walloon Series, and we have amended the name to Injune Creek Group for this sequence.

Reeves (1947, p. 1347) used the name Lower Walloon Coal Measures for the strata between the Hutton Sandstone and the Gubberamunda Sandstone. Whitehouse (1954, p. 8) called this sequence the Walloon Coal Measures. However, the Walloon Coal Measures are defined in the Ipswich district (Reid, 1921), and until correlation between the Moreton Basin and the Surat Basin is firmly established, the name Injune Creek Group is preferred for the sequence in the Injune area.

No type area has been designated for the Injune Creek Group. Near Injune only the lower part of the group is present. It is better exposed some 24 km northwest of Injune, between Pipe homestead and the plateau of Main Top, where the two local constituent formations are present. The upper unit, the Westbourne Formation, is partly eroded and capped with Tertiary basalt in this area. Sixteen km farther south, the Westbourne Formation is directly overlain by the Gubberamunda Sandstone and, being near the axis of the Merivale Syncline, is considerably thicker here than the average 120 m. The lower unit, the Birkhead Formation, is generally about 180 m thick, but is considerably thicker in the Merivale Syncline.

Birkhead Formation (Exon, 1966)

The type area is near Birkhead Creek, where it runs parallel to the Alpha/ Tambo road (between lat. 24°23'S, long. 146°22'E, and lat. 24°33'S, long. 146°22'E), and the type section is the interval from 1880 to 2244 feet (572-684 m) in Westbourne No.1. The formation extends to the south and east.

Distribution, Topography, and Vegetation: The Birkhead Formation crops out in the Tambo, Springsure, Augathella, Eddystone, Mitchell, Roma, Taroom, and Mundubbera Sheet areas. In the Eddystone Sheet it occupies a sinuous belt between 6.5 and 19 km wide, trending south-southeast in the west, and latitudinally in the south. It extends across the southwestern part of Taroom Sheet area, thence north near the axis of the Mimosa Syncline, and finally southeast across the southwest corner of the Mundubbera Sheet area.

The basal sandstone is well exposed in the Injune area. Elsewhere sandstone generally crops out as rounded boulders but the other sediments are poorly exposed. The formation is covered with thick clay soil which supports a dense growth of brigalow, belah, and wilga scrub (the calciphile flora of Jensen, 1926, p. 33) in contrast to the open forest of pine, wattle, ironbark, and lancewood (Jensen's calciphobe flora) on the Hutton Sandstone. The base of the Birkhead Formation was placed beneath the lowest calcareous sublabile or labile sandstone and above the generally non-calcareous quartzose Hutton Sandstone. The change in vegetation occurs at this lithological boundary, and has proved useful in mapping. Some low cuestas, generally composed of calcareous beds, are the only features with appreciable relief.

Lithology: The Birkhead Formation consists mainly of sublabile to labile calcareous sandstone containing ovoid sandy or silty calcareous concretions.

In the western part of the Eddystone Sheet area, where the formation is overlain by the Adori Sandstone, it is about 180 m thick. The uppermost 120 m consists of grey carbonaceous siltstone and mudstone, with subordinate fine to medium-grained lithic sandstone and a few thin seams of coal and beds of cone-in-cone limestone. The basal part of the sequence is 60 m thick, and consists of medium-grained friable sublabile sandstone with some calcareous concretions. In places (e.g. Lambing Creek 1.5 km northeast of Billin homestead) the base of the sequence consists of 6 m of quartz-rich gritty sandstone containing fossil wood.

The fine-grained sediments are laminated to thin-bedded; the sandstone ranges from medium to thick-bedded, and is commonly poorly bedded, and in places cross-bedded.

The sequence in the central and eastern part of the Eddystone Sheet area is similar, but is slightly thicker and is overlain by the labile Springbok Sandstone. The lower part of the formation consists mainly of very fine to medium-grained buff to brown poorly bedded cross-bedded sublabile sandstone. Eddystone BMR No. 47 (Mollan et al., 1965) shows that the sequence consists of about 70 percent sandstone and that most of the remainder is siltstone. The large calcareous concretions in the friable non-calcareous sandstone were probably formed during diagenesis.

The lower part of the formation is at least 42 m thick in Eddystone BMR No. 47, but absent in water bore B818 near Oakwells homestead. Some leached brown coarse sublabile sandstone with calcarous patches, chert pebbles up to 12 cm in diameter, and clay clasts is exposed a kilometre south of Eddystone BMR No. 47, and is probably stratigraphically just above the top of the hole. The middle part of the sequence is essentially the same as the upper part of the sequence in the western part of the Eddystone Sheet area.

In the Taroom and Mundubbera Sheet areas the Birkhead Formation is at least 150 m thick. In the Injune area a lower calcareous sandy sequence from 30 to 60 m thick is overlain by a sequence of alternating shale, sandstone, and coal seams, about 90 m thick.

The lower calcareous sequence is well exposed above the scarps of Hutton Sandstone south of Hutton Creek, and along Injune Creek and its tributaries north-east of Injune. The sequence consists of medium to coarse-grained poorly sorted lithic sublabile or labile sandstone, with an argillaceous or muddy matrix and a calcareous cement. Current-bedding, mud galls, and rare bands of lithic pebbles up to 2.5 cm in diameter have been noted in places. The fresh rock is hard, impermeable, and light khaki-grey or brown. On weathering, the calcareous cement is dissolved and the matrix becomes ironstained and crumbles to form dark brown soil. The sequence also includes hard light grey calcareous mottled cross-bedded sublabile sandstone, and a few beds of dark greenish brown medium-grained non-calcareous labile sandstone.

In other areas, the lower sequence is thinner and less sandy, and in places there is a thin pebble or cobble conglomerate at the base. The phenoclasts are composed of sedimentary rocks, such as ferruginous siltstone, and the matrix consists of calcareous lithic sandstone. The conglomerates probably indicate local disconformities.

The coal measures are poorly exposed, but the drillers' logs (Sandstedt, 1922) of six bores in the Injune/Bongwarra area show that they are about 90 m thick. The sequence consists of 66 percent 'shale', 30 percent 'sandstone', and 4 percent 'coal', with a regular alternation of shale and coal, or shale, coal, and sandstone. The 15 coal seams logged range from 1.5 m to 7.5 cm thick, with an average of 30 cm; the seam worked in the Maranoa colliery had a maximum thickness of 1.4 m. Up to nine lenticular beds of sandstone were logged.

The coal measures crop out in a quarry on the Taroom/Wandoan road about 16 km south of Taroom. The sediments have been hardened by a basalt intrusion, and the claystone and shale have been partly converted into bright purple and green porcellanite. The porcellanite is closely jointed, and thin fingers of vesicular basalt have been forced along some of the joints. Some well preserved plant fossils were seen in the porcellanite. The thin seam of coal above the porcellanite and shale does not appear to have been affected by the basalt, but the contact is obscured by weathering. Other outcrops of the upper part of the sequence consist of rounded boulders of hard yellow medium-grained poorly sorted calcareous labile sandstone or light grey sandstone containing brown mud galls and bands of coaly fragments and plant stems. In places, the sandstone is weathered to a yellow friable rock, cut by calcite veins.

Boulders of hard light green even-grained calcareous siltstone with a conchoidal fracture have also been noted. Calcareous sediments are common, and thin beds of concretionary limonite have been noted. Jensen (1926, p. 62) states that the numerous thin bands of ferruginous sandstone and shale in his Walloon Series commonly contain abundant plant fossils, and noted that the concretionary ironstone beds generally occur a short distance above a coal seam. They may represent local diastems in the sequence.

The bedding in the coal measures at Injune is slightly undulating and small normal faults were common in the Maranoa colliery.

The formation is capped with mottled sandy laterite in a number of places in the Taroom Sheet area.

Structure and Relationships: The Birkhead Formation is regionally conformable with the underlying Hutton Sandstone, although there are probably minor local disconformities. The boundary is transitional and the base of the formation is taken at the top of the uppermost buff quartzose sandstone which generally underlies the lowermost calcareous bed in the Birkhead Formation. In the Eurumbah Dome, in the Roma Sheet area, there is at least 60 m of fine to pebbly sandstone at the base of the Birkhead Formation.

The top of the formation was seen only in the Eddystone Sheet area. In the west, the formation is overlain by the Adori Sandstone with regional conformity, but scouring at the boundary, as seen in the Tambo Sheet area, suggests local disconformity. In the east, the formation is overlain conformably by the Springbok Sandstone, which consists largely of a sequence of fine to coarse-grained cross-bedded labile sandstone up to 45 m thick.

Environment of Deposition: Much of the formation was probably deposited in a shallow swamp, although the lower part consists of lake, delta, and subordinate stream deposits. The abundance of coal suggests prolific plant growth and a quiet reducing environment, and the regular alternation of sandstone, shale, and coal was probably due to periodic variations in rainfall. The calcareous sediments were probably precipitated chemically in a closed basin. The deposition of the calcium carbonate may have been controlled by the amount of carbon dioxide in the water. During periods of accumulation of plant matter, there was little clastic sedimentation, and probably poor circulation of water. The carbon dioxide produced by the decay of vegetation would inhibit precipitation of calcium carbonate until the water was saturated with calcium bicarbonate. On resumption of the deposition of clastic sediments (caused by some climatic change) the decaying vegetation would be buried and the supply of carbon dioxide cut off. Some calcium carbonate may have been precipitated when the concentration of carbon dioxide was reduced, possibly by an increase in temperature or by the growing plants. The abundance of intermediate volcanic debris in the sediments indicates vulcanism in the source area.

The sandy lower part of the formation was mainly deposited in lakes and deltas. It seems to represent the transition from the higher-energy depositional environment of the Hutton Sandstone to the typical paludal conditions which prevailed when the larger part of the Birkhead Formation was deposited. The presence of glauconite in a core in the lower part of the sequence in Eddystone BMR No. 47, and higher in the sequence in Mitchell BMR No. 6, suggests periods of marine influence.

Thickness: No sections have been measured. The thickness in various bores and wells is generally 150 to 180 m, but in the Merivale Syncline 270 m were penetrated in bore B818 near Oakwells homestead, and 222 m in the Killoran No. 1 well 16 km farther south.

Palaeontology and Age: Well preserved plant fossils and stems were seen in the Taroom Sheet area, but close jointing prevented collection of determinable specimens. The fossil plants listed by Wilcox (1926) and Whitehouse (1954) indicate that the formation is probably Jurassic in age.

A palynological report (De Jersey & Paten, 1964) indicates a Middle Jurassic age for the 'Walloon Formation' of Union Oil Development Corp.; the Walloon Formation can be equated with the Birkhead Formation. (Evans, 1966b) placed the Birkhead Formation in his palynological unit J4, of Middle Jurassic age.

Springbok Sandstone

The Springbok Sandstone, overlying the Birkhead Formation, crops out in the Eddystone and Mitchell Sheet areas. It was named and defined by Exon (1966) as the Springbok Sandstone Lens and was raised to formation status as the Springbok Sandstone by Power & Devine (1968). The name is derived from Parish of Springbok (lat. 26°00'S, long. 148°24'E). It consists mainly of fine to medium-grained labile sandstone with subordinate siltstone and mudstone. The type section is the interval from 125 to 165 feet (38.1-50.3 m) in BMR Mitchell No. 3 (lat. 26°04'S, long. 148°22'E).

The area of outcrop is much greater than was stated by Exon (1966). In the Eddystone Sheet area the formation extends from the southeastern corner almost halfway across the Sheet, and pinches out a few kilometres east of the Adori Sandstone. It also extends across the northeast corner of the Mitchell Sheet area and into the Roma Sheet area. The formation is better exposed than the underlying more muddy sediments of the Birkhead Formation.

The sandstone ranges from labile to sublabile and from lithic to feldspathic. It is largely fine-grained, but coarser poorly sorted beds are common, and fine conglomeratic beds are also present. The bedding ranges from medium to thick, and is thicker in the coarser-grained beds. Scour and planar cross-beds are widely developed.

In outcrop, ovoid calcareous concretions are common in the greenish or yellowish brown sandstone. Subsurface it is white or pale green, tight, and clayey. It generally contains fragments of green and black volcanic rocks, clay, and feldspar, and a little muscovite. The minor constituents include carbonaceous fragments and plant remains, biotite, magnetite, and rare glauconite. The pebbles consist of quartz and some green volcanics.

The siltstone is generally labile, carbonaceous, and micaceous. It ranges from grey to greenish, and may be calcareous. Grey mudstone and thin coal seams occur in some localities.

The base of the formation is taken at the top of the highest thick mudstone sequence in the Birkhead Formation, and the top is apparently conformable under the Westbourne Formation. The formation fills a similar position to the Adori Sandstone, but contains more volcanic detritus, and is highly calcareous. The orientation of the cross-beds is highly variable. The formation is a poor aquifer which gives salty water in some areas.

The presence of abundant angular fragments of intermediate volcanics and fresh plagioclase suggests a nearby source area and contemporaneous vulcanism. Most of the beds were deposited in a fluviatile environment, but the abundance of lime and the presence of some coal indicate periods of lacustrine to paludal deposition. Periods of marine influence are indicated by glauconite.

The formation is 12 m thick in the type section, but is 45 m thick farther west in the axial region of the Merivale Syncline. The only fossils found are some plant debris in the coals. On stratigraphic grounds its age is probably Middle Jurassic.

Adori Sandstone (Exon, 1966)

Distribution, Topography, and Vegetation: The Adori Sandstone crops out in the Tambo, northeastern part of the Augathella, and western part of the Eddystone Sheet areas. In the Eddystone Sheet area it occupies a belt about 3 km wide trending south-southeast from 3 km west of Mount Playfair to 6 km east of Winneba homestead, where it pinches out. It forms low cuestas and strike ridges in the plains on the Birkhead Formation. The soil is sandy and is generally covered by scrub but in places supports forests of cypress pine.

Lithology: The formation consists largely of clayey sublabile sandstone, with minor pebbly and gritty sandstone, siltstone, and claystone. The sandstone is medium to thick-bedded and in places cross-bedded. It is white, soft, and commonly porous. The grains range from fine to coarse and are subangular. The sandstone consists mainly of quartz and some clayey labile fragments, set in a clay matrix, with less abundant, but widespread, black cherty fragments and, in places, a little muscovite and a green soft mineral which may be glauconite. Worm casts and tubes, plant impressions, and clay clasts also occur.

The pebbles consist of quartz, acid volcanics, and quartzite, and lesser amounts of chert and sandstone. The gritty beds contain angular quartz and a few cherty fragments.

Thin-bedded grey to buff siltstone and white claystone interbeds constitute only a minor part of the formation. Claystone also occurs as large fragments in the sandstone, indicating short, probably local, depositional breaks. Such breaks are also indicated by the presence of irregular erosional surfaces within the unit. The ironstone beds in the formation are probably of secondary origin. A measured section (E4) is shown in Figure 16.

Five thin sections were examined: all contain abundant quartz and quartzite grains set in a matrix of clay; silty and shaly fragments, feldspar grains, and voids are present in some specimens. The average composition is about 40 percent quartz, 10 percent quartzite, 5 percent feldspar, 5 percent shaly and silty fragments, 25 percent clay matrix, and 10 percent voids. The accessory minerals are muscovite, biotite, zircon, and iron oxide. One of the rocks contains a few fragments of porphyritic acid volcanics.

Relationships and Thickness: The Adori Sandstone is apparently conformable on the Birkhead Formation, but in the Tambo Sheet area the contact with the underlying siltstone is scoured. Pebbles are largely confined to the base of the formation. The formation thins to the southeast from about 60 m, and finally pinches out east of Winneba homestead. The Springbok Sandstone is apparently equivalent to the Adori Sandstone and was deposited in a similar environment.

Environment of Deposition: The thick bedding, fairly coarse grainsize, and strong cross-bedding point to fluviatile deposition. The abundant clay matrix was probably formed by the diagenetic alternation of feldspar. The orientation of the cross-beds in the Eddystone Sheet area indicates a general northerly source, and in the Tambo Sheet area the cross-beds strongly suggest a source to the northeast. The formation is an aquifer.

Palaeontology and Age: Only plant impressions have been found. The spores in the overlying and underlying formations indicate that the Adori Sandstone belongs to Evans' Jurassic unit J5 (1966b).

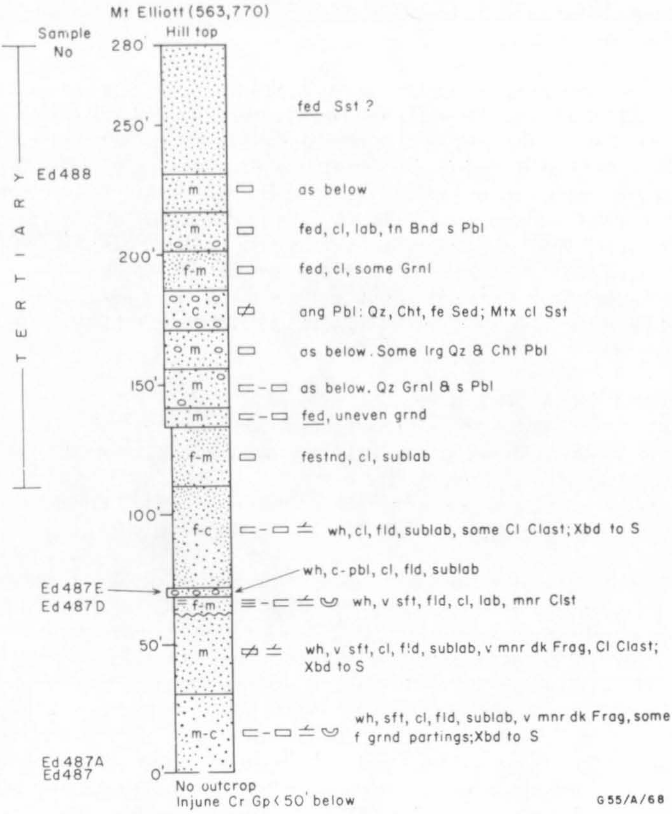

Fig. 16. Measured section of the Adori Sandstone.

Westbourne Formation

Gerrard (1964) proposed the name Westbourne Formation for the sequence from 1279 to 1651 feet (389.8-503.2 m) in the Westbourne No. 1 well in the Augathella Sheet area. Mapping in the Tambo Sheet area (Exon et al., 1966b) has confirmed that this is the Upper Intermediate Series of Woolley (1941), as suggested by Gerrard, and the name was published in Exon (1966). The type section in Westbourne No. 1 contains fine-grained sandstone, siltstone, and shale identical with those of the Westbourne Formation in the Eddystone Sheet area.

Distribution, Topography, and Vegetation: The formation crops out in the Tambo Sheet area, the northeastern part of the Augathella Sheet area, the western and southern parts of the Eddystone Sheet area, and the northern part of the Mitchell Sheet area. It forms a belt from 1.5 to 13 km wide, extending southwards down the western side of the Eddystone Sheet from near Cunno homestead to Winneba homestead, and thence eastwards along the northern boundary of the Mitchell Sheet. It swings north in the Merivale Syncline and then south off the Sheet. It is very widespread subsurface, with a distinctive high-intensity gamma-ray log.

The formation generally forms a slope below the hills of the overlying sandstone units, and is covered with fairly open brigalow scrub. In the western part of the Eddystone Sheet area more resistant beds near the top and bottom of the formation form low cuestas.

Lithology: The formation is poorly exposed, and the most common outcrops consist of siltstone, in places calcareous, and fine-grained soft friable quartzose to sublabile sandstone. The siltstone is grey, carbonaceous, and micaceous, and grades into mudstone. It is laminated to thin-bedded and some outcrops contain discoidal ironstone concretions, which were probably originally calcareous. The sandstone is buff, thin to thick-bedded, and contains feldspar, a little muscovite and biotite, and some fragments of black chert. In places it contains large calcareous nodules. It is commonly interbedded with siltstone and shows some cross-bedding and contemporaneous slumping. Both the siltstone and the sandstone contain plant debris. Some thin beds of hard calcareous siltstone and fine sandstone are present in the lower part of the sequence.

In Eddystone BMR No. 49 and No. 50 (see Mollan et al., 1965) the sequence consists predominantly of laminated to thinly bedded carbonaceous, micaceous siltstone and mudstone, in part calcareous. A little quartzose sandstone is also present. Cross-bedding and small-scale slumping are common. A little altered glauconite(?) has been recorded in a core 24 m below the top of the formation in Eddystone BMR No. 50, and 9 m below the top in Eddystone BMR No. 48 (Mollan et al., 1965).

Eight thin sections were examined. Three, from sediments low in the sequence, consist of calcareous fine-grained sandstone or siltstone containing about 50 percent calcite, 30 percent quartz, 3 percent feldspar, 3 percent shaly fragments, and accessory muscovite, iron oxide, tourmaline, zircon, and, in some, rutile and biotite. Three consist of fine-grained sandstone containing abundant angular quartz, subordinate feldspar and muscovite, and some fragments of shale and quartzite. Green biotite, iron oxide, tourmaline, and zircon are accessory. One of the sandstones is very porous; another contains a matrix of iron oxide. Another sandstone contains 50 percent quartz, 40 percent clay matrix, and the usual minor constituents. The only siltstone examined consists largely of quartz, with subordinate iron oxide and muscovite, and a little green biotite.

Relationships: The formation is conformable with the underlying Adori Sandstone west of Mount Elliott, and with the Springbok Sandstone to the east. There may be a disconformity between the Westbourne and Birkhead Formations where the Adori Sandstone and Springbok Sandstone are absent, but there is no field evidence of this. The boundary with the medium-grained Adori Sandstone is transitional and has been taken immediately below the lowest thick siltstone or mudstone bed. The boundary with the Springbok Sandstone is taken, in outcrop, immediately above the highest calcareous labile sandstone bed, or immediately below the lowest fine-grained buff friable sublabile sandstone bed. Subsurface the boundary is taken at the top of the highest coal seam, and generally above the highest medium-grained labile sandstone.

Environment of Deposition: The fine grainsize, thin bedding, and low-angle cross-bedding, and the presence of some calcareous material and abundant carbonaceous material, all suggest that the Westbourne Formation was deposited in a predominantly lacustrine environment. The sandstones are generally strongly cross-bedded and were probably deposited in a delta. The orientation of the cross-beds is highly irregular. The presence of acritarchs and altered glauconite in Eddystone BMR No. 50 suggests marine influence at some levels.

Thickness: The formation is between 105 and 120 m thick in the Eddystone Sheet area (cf. 113 m in the type section in Westbourne No. 1) except in the Merivale Syncline, where it is probably up to 300 m thick.

Palaeontology and Age: No marine macrofossils have been found, and none of the poorly preserved plant remains have been identified. Evans (1966b) has identified Upper Jurassic spores (units J5 and J6) and acritarchs.

Hooray Sandstone

Woolley (1941) named the Hooray Sandstone from Hooray Creek, and measured a section in Hooray and Mount Pleasant Creeks. The name was first published by Hill & Denmead (1960). The type section, in Hooray Creek 19 km east-northeast of Tambo, was measured and illustrated by Exon (1966). In the type area the formation could probably be subdivided into two formations (Exon, 1966): probably only the upper part is present in the Eddystone Sheet area.

Distribution, Topography, and Vegetation: The Hooray Sandstone crops out in the Tambo, Augathella, Eddystone, and Mitchell Sheet areas. In the western part of the Eddystone Sheet area it forms a north-northwesterly belt, consisting largely of dissected plateaux with steep scarps. Many of the plateaux are lateritized, and some of them are capped with Tertiary sediments. The formation is gently dipping, and bedding trends are rare except near the base, where some cuestas have been formed. Where flat surfaces are developed (on plateau tops and, in places, near the base of the formation) a sparse eucalypt savannah prevails; elsewhere the outcrops are covered with thick scrub.

Lithology: The formation consists mainly of white clayey coarse-grained sublabile sandstone, containing scattered pebbles (Fig. 17). It is medium to thick-bedded, cross-bedded, and contains some worm tubes. The six thin sections examined show the sandstone to be remarkably uniform. It is even-grained and consists of 40 to 60 percent subangular clasts of quartz and quartzite, 5 to 10 percent feldspar, and up to 15 percent of fine-grained sediments set in a clay matrix. The accessories include widespread iron oxide and a little mica, zircon, and tourmaline. In the stratigraphic boreholes in the northern half of the Mitchell Sheet area (Exon et al., 1966a) sparse glauconite has been found. The clay matrix was probably largely derived by the alteration of feldspar. The formation is a good aquifer.

Thick-bedded cross-bedded conglomerate is widespread. It generally contains pebbles of quartz, porphyritic and fine-grained acid volcanics, chert, sediments, and less commonly fossil wood, set in a white sandstone matrix. The formation also contains some feldspathic and quartzose sandstone, and some beds of white clayey siltstone and claystone.

Relationships: The pebbly Hooray Sandstone is apparently conformable on the silty and less competent Westbourne Formation, but in the Tambo Sheet area the contact is scoured. In the Eddystone Sheet area only the upper conglomeratic part of the formation is present. A few kilometres east of the Maranoa Anticline to the south of the Eddystone Sheet, the Hooray Sandstone passes laterally into the Bungil Formation, Southlands Formation, and Gubberamunda Sandstone.

Environment of Deposition: The high-angle cross-bedding and coarse grain-size of the sediments indicate fluviatile deposition, but the presence of glauconite points to periods of marine influence. The orientation of the crossbeds is highly irregular. Farther northwest, the source of the equivalent part of the Hooray Sandstone was from the Eddystone Sheet area. The formation is estimated to be 120 m thick in the Eddystone Sheet area, compared with 75 m for the complete sequence and 30 m for the equivalent upper part of the sequence in the type area (Exon, 1966). The Hooray Sandstone was probably derived from older sandstones and conglomerates.

Age: No identifiable plants or marine fossils have been found in this area. On stratigraphic correlation the formation extends from Upper Jurassic to Lower Cretaceous.

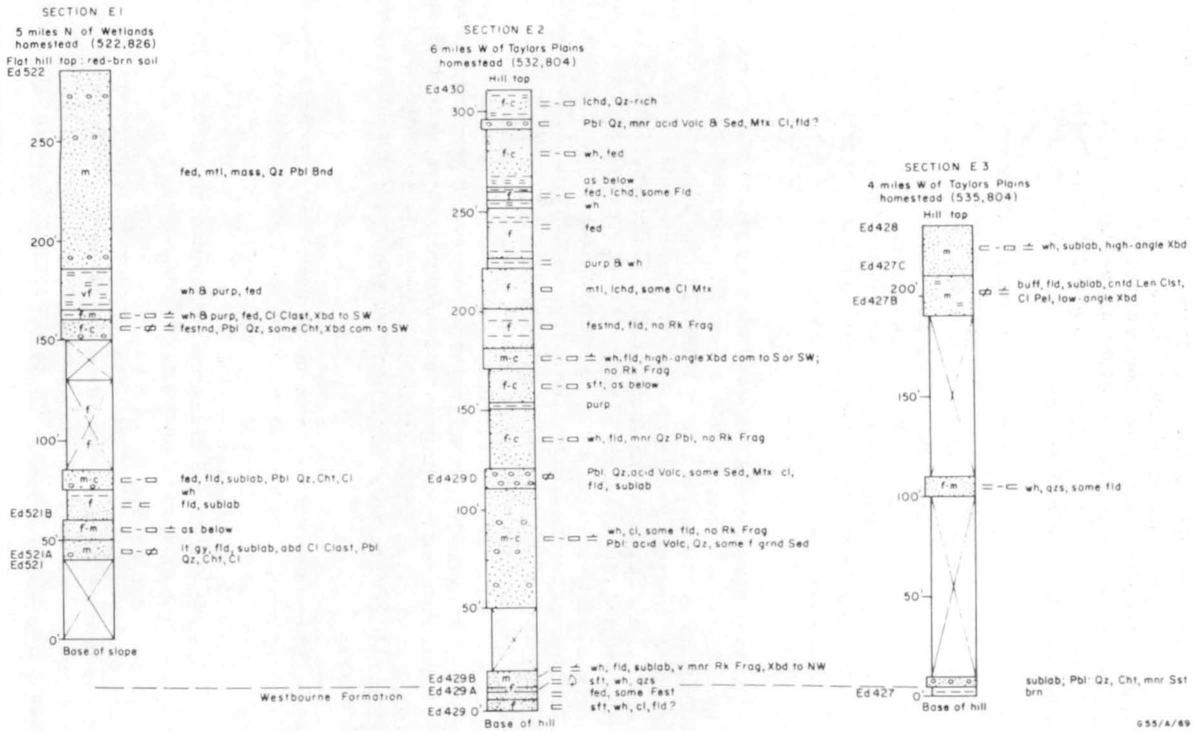

Fig. 17. Measured section (E1, E2, and E3) of the Hooray Sandstone.

Gubberamunda Sandstone

The name Gubberamunda Sandstone was introduced by Reeves (1947), and the type area along the main Roma/Injune road, 32 to 38 km north of Roma, was nominated by Day (1964).

Distribution, Topography, and Vegetation: The formation crops out in the Roma, Mitchell, and Eddystone Sheet areas. In the southeastern part of the Eddystone Sheet area it occupies a small area west of Hidden Springs homestead. The formation is easily eroded, and forms low rises and cuestas in the plains on the Injune Creek Group. The sandstone weathers to a white, greyish, or reddish soil, and is generally covered by scrub.

Lithology: The formation consists of sandstone and conglomerate with a little siltstone and claystone. The sandstone is fine to coarse-grained and pebbly, and quartzose to sublabile; it consists of subangular grains of quartz, feldspar, and white rock fragments, with a few grains of black chert and muscovite, set in a clay matrix. The sandstone is white to buff, soft, porous, and medium to thick-bedded and cross-bedded. Some beds contain abundant plant impressions or clay clasts. The conglomerate has a sandstone matrix, and contains numerous pebbles of quartz, chert, and porphyritic acid volcanics and some pebbles of chalcedony and quartzose sandstone. The siltstone is grey-green and thin-bedded to laminate. In the northern part of the Mitchell Sheet area (Fig. 18, sect. M1) the upper part of the formation contains abundant micaceous carbonaceous siltstone and mudstone, which do not crop out in the Eddystone Sheet area. The porous sandstone and conglomerate beds are good aquifers.

The three medium-grained sandstones examined contain about 60 percent quartz, 5 percent feldspar, 15 percent siltstone and shale fragments, 20 percent shaly matrix, and up to 10 percent quartzite. Iron oxide, muscovite, and biotite are common accessories.

Relationships: The formation is apparently conformable with the underlying Westbourne Formation. In the Maranoa River, to the south of the Eddystone Sheet boundary, the contact is transitional over a distance of about 6 m, and the siltstones of the Westbourne Formation intertongue with beds of Gubberamunda Sandstone. The tops of the siltstone beds are scoured by the overlying sandstones. The top of the highest thick siltstone bed is taken as the contact.

Environment of Deposition: The large-scale cross-bedding and fairly coarse grainsize suggest that the Gubberamunda Sandstone was deposited in a fluviatile environment, and the presence of abundant feldspar and a clay matrix suggest deposition close to the source area. The orientation of the cross-beds indicates derivation from the south or southeast.

Thickness: The formation is 60 m thick in the type area, and is estimated to be 60 to 75 m thick in the Eddystone Sheet area. It thins to the west across the Mitchell Sheet area, and 30 km east of the Maranoa Anticline grades laterally into the lower part of the Hooray Sandstone.

Palaeontology and Age: No shelly fossils have been found, but the formation contains some plant impressions. The spores belong to Evans' (1966b) Upper Jurassic spore unit J6.

Southlands Formation (new name)

The Southlands Formation is named after Southlands Parish and Holding. The type section (Fig. 19) is in the western slope and cliffs of the Great Dividing Range, 6 km west of Hidden Springs homestead (grid ref. 644771).

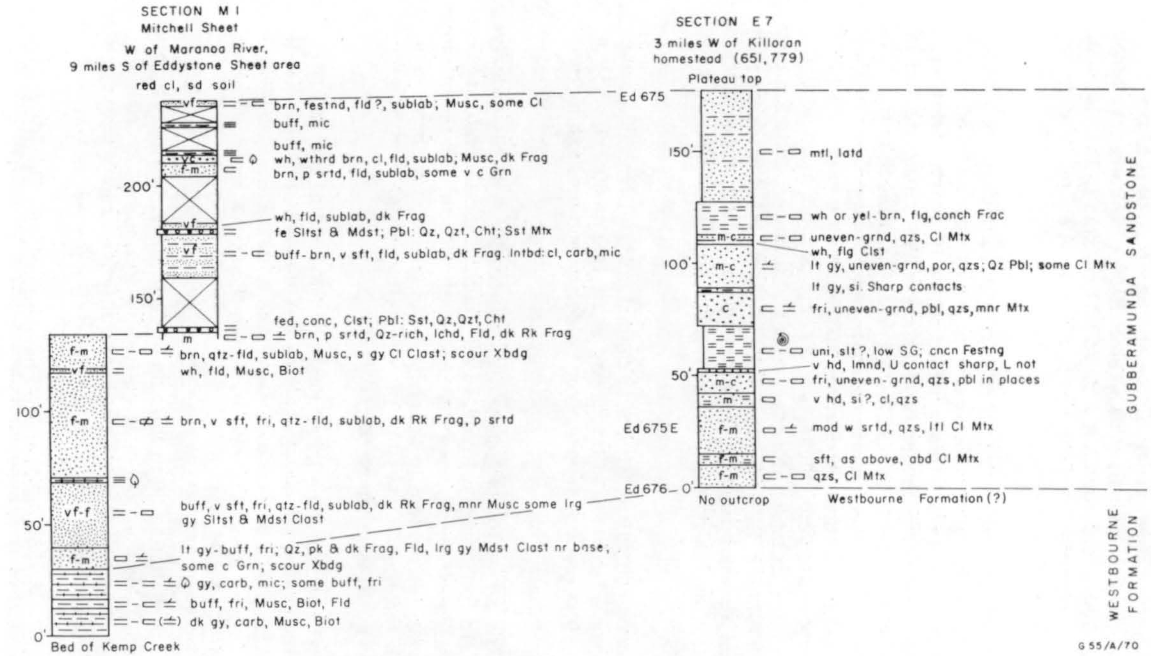

Fig. 18. Measured sections (E7 and M1) of the Gubberamunda Sandstone.

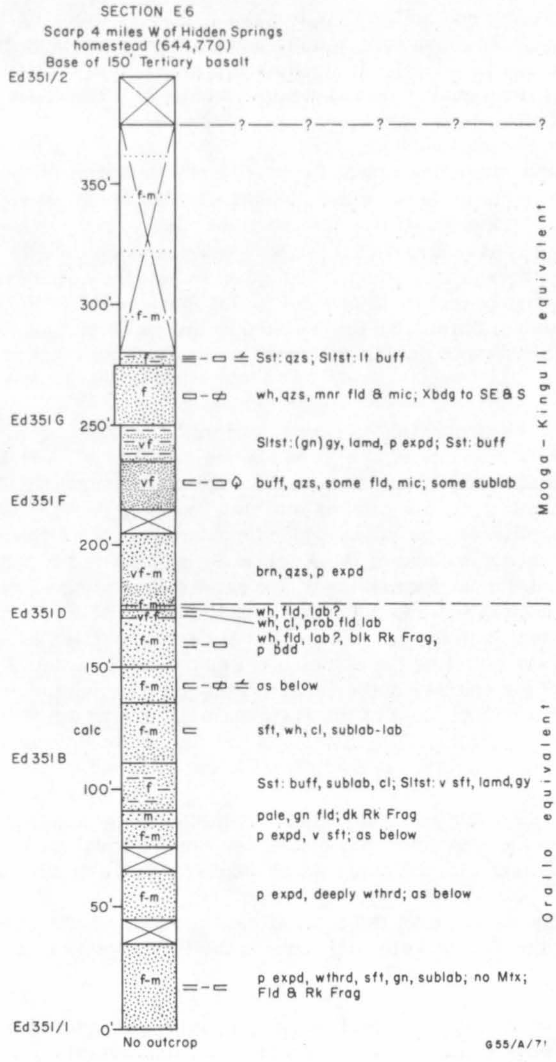

Fig. 19. Measured section of the Southlands Formation.

Distribution, Topography, and Vegetation: The formation forms a belt of country, generally of fairly low relief, from the Alicker Anticline near the eastern margin of the Mitchell Sheet area, westwards across the Mitchell and Eddystone Sheets. It pinches out about 13 km west of the Forest Vale Anticline, in the central-northern part of the Mitchell Sheet area. It is generally covered with brigalow, wilga, belah, sandalwood, and bottle tree scrub, but the more sandy areas have a calciphobe type of vegetation.

Lithology: The lower half of the formation consists largely of fine to medium-grained calcareous clayey sublabile to labile sandstone, containing dark rock fragments and a few pebbly bands. It is generally thickly bedded and cross-bedded. The upper half is finer in grain and less labile. It consists largely of thinly bedded mudstone, siltstone, and fine-grained quartzose to sublabile sandstone. There are also some calcareous beds and a few beds of coarse gritty sandstone.

Six thin sections were examined. Five, from the type section E6 (Fig. 19) illustrate the change from the lower clayey calcareous labile sandstone to the upper clean quartz-rich sandstone. In all five thin sections, the proportion of feldspar is less than 10 percent and averages 5 percent, and shaly rock fragments form less than 15 percent, and average 10 percent. The quartz content increases from about 30 percent in the lower 175 feet to 75 percent in the upper part and the clay content falls from about 50 to 5 percent. One thin section of the upper part of the unit, some 12 km farther east, consists of quartz-rich sandstone similar to that at the top of section E6.

Relationships: The formation is only known in the outcrop area, where it is equivalent to the Orallo Formation, Mooga Sandstone, and Kingull Member of the Bungil Formation; in the subsurface the wireline log characteristics of these subdivisions are recognizable. On the Alicker Anticline, west of the type area of these three units, the distinctive coarse cross-bedded sandstone in the lower part of the Mooga Sandstone pinches out. West of the Alicker Anticline it is not possible to map the three units separately. In general, the upper part is equivalent to the Mooga Sandstone and Kingull Member, and the lower part to the Orallo Formation. This correlation is consistent with the gross lithological characteristics of the units. West of the Forest Vale Anticline the Southlands Formation thins and intertongues with the lower part of the coarser and cleaner Hooray Sandstone, and near Mount Elliott homestead, about 13 km east of the Maranoa Anticline in the Mitchell Sheet area, it becomes unrecognizable. The siltstone beds low in the Hooray Sandstone west of here may be equivalent to the Southlands Formation.

The Southlands Formation is apparently conformable with the underlying Gubberamunda Sandstone. The more labile sandstone in the basal part of the Southlands Formation contrasts with the quartz-rich Gubberamunda Sandstone.

Thickness: The thickness of the formation is generally 120 to 150 m, but it thins rapidly west of the Forest Vale Anticline. In the type section it is about 120 m thick.

Environment of Deposition: The lower thick-bedded cross-bedded medium-grained labile calcareous sandstone sequence was probably deposited in fluviatile and lacustrine environments relatively close to the source area. The upper cleaner finer-grained thin-bedded sequence, with low-angle cross-bedding, was probably deposited in a restricted lacustrine environment. The formation was probably derived from pre-existing sediments.

Palaeontology and Age: Leaf fragments and fossil wood are abundant, but none of the material has been identified. Microfossils found in the equivalent Orallo/Mooga/Kingull sequence (P.R. Evans, pers. comm.) belong to Evans' spore units J5-6 and K1a (Evans, 1966a). These divisions are believed to range from Upper Jurassic to Lower Cretaceous (P.R. Evans, pers. comm.).

Claravale Sandstone Member of the Bungil Formation (new name)

Origin of Name and Type Section: The Claravale Sandstone Member of the Bungil Formation (see Exon & Vine, 1969) is named from Claravale homestead in the Mitchell Sheet area. The type section is in the lowermost scarp on the western side of Long Gully, 6 km northwest of Claravale homestead (grid ref. 627752).

The sequence consists of 7 m of fine to medium-grained brown quartzose sandstone with some feldspar grains, clayey rock fragments, and clay matrix. It contains some coarse grains and a few pebbles of quartz and quartzite, and small-scale cross-bedding and ripple marks, and is medium-bedded to very thickly bedded. Wood impressions, carbonaceous plant remains, and worm casts are common.

Distribution, Topography, and Vegetation: The member is confined to the Merivale Syncline. It forms low scarps at the base of stepped mesas, in contrast with the low relief of the underlying formation. It extends from Landreath homestead in the northeastern part of the Mitchell Sheet area, northwest to the Eddystone Sheet boundary, and thence southwest to the Maranoa River. In the Eddystone Sheet area it crops out as small outliers west of the Great Dividing Range. It is covered by sand and supports a calciphobe vegetation.

Lithology: The type section consists mainly of sandstone, subordinate siltstone, and mudstone which commonly contains plant remains. The sandstone ranges from white to brown, and is porous. In places it contains quartz pebbles and bands of clay clasts. Accessories include quartzite and shale fragments, some magnetite, and a little muscovite and tourmaline.

Relationships: The Claravale Sandstone is a member of the Bungil Formation. It is structurally conformable on the equivalent of the Kingull Member within the Southlands Formation. The presence of a 15-cm ferruginized zone at the top of the Southlands Formation (grid ref. 630770), and the marked change from the fine-grained incompetent sediments of the Southlands Formation to the Claravale Sandstone, suggest the presence of a disconformity and possibly a brief period of subaerial weathering. In the Mitchell Sheet area the member is conformably overlain by the Nullawurt Sandstone Member. East of the farthest extent of Claravale Sandstone, the Nullawurt Sandstone directly overlies the Kingull Member, but to the west the equivalent of the Nullawurt Sandstone within the Hooray Sandstone directly overlies the Southlands Formation.

Thickness: The thickness ranges up to 24 m, but is generally about 9 m.

Environment of Deposition: The attitude of the cross-beds indicates deposition from easterly flowing streams. The claystone beds may have been deposited away from the main channels during floods. The fairly coarse deposits were confined to the downwarp of the Merivale Syncline; equivalents elsewhere are much finer in grain. The member has not been identified subsurface, and it was probably only deposited around the margins of the syncline.

Palaeontology and Age: The member contains wood impressions, and leaf fragments are common in the finer beds. None of the plants have been identified. The member overlies the Lower Cretaceous Mooga Sandstone equivalent and is considered to be Lower Cretaceous. Its equivalents fall within Evans' (1966a) spore unit K1a, of probable Lower Cretaceous age (P.R. Evans, pers. comm.).

Doncaster Member of the Wallumbilla Formation

The Doncaster Member as defined by Vine & Day (1965) in the northern Eromanga Basin consists of 'mainly blue grey mudstone, with subsidiary glauconitic mudstone and glauconitic siltstone'. It was included in the Wallumbilla Formation by Vine, Day, Milligan, Casey, Galloway, & Exon (1967).

Distribution, Topography, and Vegetation: The member crops out widely in the Great Artesian Basin. It covers a few square kilometres in the extreme southwestern part of the Eddystone Sheet area, where it is commonly overlain by lateritized Tertiary sediments. It forms black-soil plains which are well grassed and treeless, except where the member is covered by sand and gravel from the overlying Tertiary sediments, and along streams. Bedding trends are not discernible.

Lithology: The member consists largely of grey laminated siltstone and mudstone which weather yellow-brown. It also includes thin-bedded fine-grained hard nodular calcareous sediments. The thin ironstone beds cropping out were probably originally calcareous. The weathered khaki sandstone, near the base of the formation, is glauconitic.

The base of the member is exposed north of Hoganthulla Creek, 1.5 km west of the Eddystone Sheet boundary; it consists of partly silicified and partly calcareous sublabile sandstone and gritty sandstone.

Relationships: The Doncaster Member is apparently conformable on the underlying Hooray Sandstone and there is a sharp change in the type of soil, topography, and vegetation at the boundary. The sandstone in the lower part of the member, which is interbedded with siltstone and shale, is similar in lithology to the sandstone of the Hooray Sandstone. The base is taken as the lowest bed of thick mudstone or siltstone. In the Eddystone Sheet area, the member is unconformably overlain by strongly lateritized Tertiary sediments. The leached structureless white clayey rock below the coarser Tertiary sediments may be part of the member.

Environment of Deposition: The fine grainsize and thin bedding indicate deposition in moderately placid water; abundant shelly fossils found elsewhere indicate marine conditions.

Thickness: Only about 60 m of the Doncaster Member are present in the Eddystone Sheet area.

Palaeontology and Age: The Aptian age is based on abundant marine fauna (Day, 1964); no fossils have been found in the Eddystone Sheet area.

TERTIARY BASALT AND SEDIMENTS

Basalt

Distribution and Topography: Remnants of Tertiary basalt flows crop out in the northern and southern parts of the Great Dividing Range in the Eddystone Sheet area, and smaller outliers occur in the northern half of the Sheet as far west as longitude 147°23'E. The three small outliers farther west have been photo-interpreted.

In the Great Dividing Range, the basalt forms small steep-sided plateaux and mesas with a maximum relief of about 250 m near the northern boundary of the Eddystone Sheet area. Mount Hutton and Main Top in the southern part of the range are part of an elongated plateau of basaltic flows.

Similar basalt flows, with a few interbeds of feldspathic sublabile sandstone, crop out in the northern part of the Taroom Sheet area along the axial zone of the Mimosa Syncline. The basalts have an undulating topography with a maximum relief of about 30 m, and an average of about 15 m. Towards the northern edge of the mapped area, laterite has been developed on the basalt plains.

There are also small areas of basalt about 16 km northeast and 24 km south-east of Injune, and on the Mundubbera Sheet area near Mount Ox and near Kennedy Peak.

Lithology: In the Eddystone Sheet area fine-grained basalt predominates. Some of the flows are vesicular and amygdaloidal, others consist of dense fresh basalt with platy jointing. Many of the flows have been deeply weathered. The two flows in the Murphy

Tableland outlier consist of medium-grained alkaline olivine basalt and fine-grained olivine-free alkaline basalt. The olivine basalt consists of andesine-labradorite, titanaugite, olivine, interstitial anorthoclase and analcite(?), and magnetite. The fine-grained basalt consists of abundant chabazite(?), orthopyroxene, plagioclase, and magnetite. The topmost flow at Main Top is an olivine-free basalt containing pigeonite, augite, and andesine-labradorite.

North of Gwambagwine, the sequence consists of vesicular, amygdaloidal, and massive basalts interbedded with subordinate feldspathic sublabile sandstone.

The basalts are similar in composition, and consist of laths of labradorite, granular augite, and abundant iron oxide. The more massive rocks contain small phenocrysts which have been altered to iddingsite and hematite. Flow structure is well developed in some of the rocks and some contain small amygdales up to 0.15 cm in diameter. Volcanic glass forms about 5 percent of the vesicular basalt, and iron oxide up to 15 percent; the vesicles form as much as 40 percent of the rock.

The vesicles and amygdales are lined or filled with blue opaline silica. In the vesicles a similar mineral forms botryoidal masses composed of individual subspherical masses up to 0.3 cm in diameter. The individual hemispherical masses are composed of up to ten thin brittle concentric layers, separated by a gap from one to five times as wide as the layers themselves. This material is weathered and is strongly ironstained.

In one area near Roeburn homestead, joints up to 15 cm wide, filled with green-yellow opaline silica, were noted.

The interbeds of sandstone are usually from 60 to 120 cm thick. They consist of medium to fine-grained feldspathic sublabile sandstone, and are commonly weathered and strongly ironstained. In places they have been metamorphosed by the overlying basalt, and the iron-bearing minerals have been altered to hematite.

Near Injune there are two different types of basalt. The first, southeast of Injune, contains about 5 percent olivine phenocrysts set in a groundmass composed of laths of plagioclase, granular augite and magnetite, and a little interstitial glass. The second northeast of Injune, contains up to 20 percent olivine phenocrysts set in an intergranular groundmass of pigeonite, plagioclase, and magnetite.

Near Mount Ox, a narrow strip of massive basalt crops out. The rock is composed of a few scattered phenocrysts of plagioclase, set in a groundmass of fine-grained plagioclase, augite, and abundant magnetite.

Relationships and Thickness: The basalt outliers in the northern part of the Eddystone Sheet area rest unconformably on Lower Jurassic sediments whereas the basalt in the outlier of Mount Hutton and Main Top rests unconformably on the Injune Creek Group, Gubberamunda Sandstone, Southlands Formation, and Bungil Formation. The outliers in the northern part of the Eddystone Sheet are remnants of an extensive plateau of basalt which extended across much of the Springsure Sheet area to the north. The maximum thickness of the basalt is about 250 m near the northern boundary of the Eddystone Sheet area. The basalt outliers north of Attica homestead rest on strongly silicified Hutton Sandstone.

The basalts in the Eddystone Sheet area were probably derived from fissures and vents which are now represented by basaltic dykes and plugs (see p.79). The Tabor Gabbro is also probably genetically related to the basalt.

North of Gwambagwine the sequence of basalt and sandstone occupies a large valley in the Hutton Sandstone. Hills of Hutton Sandstone stand up to the east and west of the basalt, and the same formation also crops out in deep creeks which have cut through the basalt. The sandstone interbedded with the basalt is similar to the Hutton Sandstone, from which it was probably derived. The basalt has a maximum thickness of about 45 m, but averages about 15 m.

The small outcrops of basalt near Kennedy Peak and near Injune are thought to be plugs, and the outcrop near Mount Ox is apparently the remnant of a small flow.

Age: The basalt flows are considered to be Tertiary because they rest unconformably on gently dipping Jurassic and Cretaceous sediments, and because the flows in the Springsure Sheet area have been dated as Tertiary by isotopic methods (A.W. Webb, pers. comm.).

Sediments

Clay and unconsolidated gravel are found in the western part of the Mundubbera Sheet area. The clay was found only near Gyranda homestead where about 18 m of brown clay, overlain by about 9 m of gravel, was encountered in BMR Taroom No. 26. Gravel is also found as a capping on a hill 12 m high near Binda Weir. It consists of pebbles and boulders of silicified sedimentary rocks up to 30 cm in diameter. Two rounded boulders containing Permian plant impressions (*Phyllotheca* sp.) were noted, and some of the pebbles consist of silicified wood.

There is no direct evidence that these deposits are Tertiary. They lie close to the Dawson River but are not part of the stream channel, nor is there any sign of ancient meanders in the area. The silicification of the gravel may be related to the climatic changes associated with the formation of the extensive cappings of laterite and silcrete. The clay is older than the gravel, but both are tentatively assigned to the Tertiary.

The lateritized quartzose sediments, which crop out in high-level outliers in the western part of the Eddystone Sheet area, rest unconformably on Cretaceous rocks which have also been lateritized. The sediments generally consist of quartz-rich clayey sandstone and pebbly sandstone, and a little conglomerate. The pebbles consist of quartz, and ferruginized and silicified sediments. The sediments are typically structureless or thick-bedded. Ferruginized, leached, and mottled zones can be seen in a 6-m section in a low scarp 3 km north of Booka homestead. The section is capped by red soil containing ferruginous pisolites. The presence of cross-bedding and plant fragments in the unlateritized sediments, the lack of marine fossils, and the coarse grainsize point to fluviatile deposition.

The lateritized Cretaceous sandstone is difficult to distinguish from the Tertiary sandstone. The Tertiary sediments are generally less than 30 m thick, but a thickness of 52 m was measured in section E4 (Fig. 16).

PERMIAN INTRUSIVE ROCKS

Auburn Complex

The Auburn Complex consists of granodiorite and minor diorite cut by dykes of dacite and andesite.

Distribution, Topography, and Access: The complex forms the eastern edge of the area mapped and crops out extensively in the central part of the Mundubbera Sheet area.

The topography is gently undulating, with a few small areas of rough hilly country. The complex is deeply weathered and mainly covered by soil. Small hills and ridges of lateritized granodiorite, up to 10 m above the plain, are common, and scattered tors crop out in the plains. The granodiorite is covered with brigalow scrub, thick timber, or well grassed parkland. Roads and station tracks afford the only access through the brigalow scrub and thickly timbered country. The soil is relatively poor and supports considerably fewer cattle than areas farther west. All the water bores are shallow, but some produce water suitable for stock.

Nomenclature and Previous Investigations: Jensen (1926) referred to the plutonic rocks and associated Palaeozoic metamorphics as the Auburn Range Complex. Denmead (1938) described the rocks in more detail in his report on the Cracow Goldfield and referred to them as the 'Auburn granodiorite' and 'Auburn granite' and included them in 'Plutonic Rocks, Granodiorite, Gabbro, etc'. on his map. He recorded a belt at least 50 km wide of gneissic rocks, granodiorite, and gabbro. Laing (1955) briefly described the outcrops near Cockatoo Creek as the Auburn Granite. We prefer the name Auburn Complex.

Lithology: The Auburn Complex consists of at least 95 percent granodiorite with subordinate diorite, and dykes of diorite, aplite, dacite, and andesite.

The granodiorite is massive and mostly medium-grained and allotriomorphic granular, but grades in places into microgranodiorite. It commonly contains up to 5 percent of plagioclase phenocrysts up to a centimetre long, and is composed of plagioclase (50-80%), quartz (40-10%), biotite (up to 15%), hornblende (up to 15%), potash feldspar (up to 15%), and accessory iron oxide and sphene. In places, hornblende is absent and only a little potash feldspar is present.

Biotite averages about 15 percent, and hornblende is commonly at least 2 to 3 percent, but in places the mafic minerals form less than 2 percent of the rock. Myrmekite forms up to 70 percent of the rock in places. The biotite and hornblende are commonly altered to chlorite, and the feldspar to epidote, clay minerals, and sericite.

The plagioclase, which is commonly zoned and twinned, occurs as phenocrysts and smaller anhedra, and with quartz in myrmekite. Many of the plagioclase crystals are stained pink by iron. Biotite occurs as small flakes or aggregates and as scattered books up to 3 cm across. The tabular green crystals of hornblende are up to 2 cm long, and some of them are twinned. Quartz occurs as anhedral grains and in myrmekite.

The diorite contains about 15 percent hornblende and only about 5 percent quartz. It has an allotriomorphic intergranular texture, and is composed of crystals of hornblende and plagioclase and large poikilitic aggregates of quartz, plagioclase, and hornblende. The extent of the diorite is not known.

The dykes intruding the granodiorite consist mainly of diorite. They range from pale yellow-brown to pale green-grey and are generally composed of stumpy laths of plagioclase, up to 1 cm long, and flakes of biotite set in a groundmass of fine granular quartz, feldspar, and myrmekite. The andesite dykes are widely distributed, but are not common. They consist of phenocrysts of plagioclase and hornblende, up to 1 cm long, set in a fine-grained green chloritic groundmass. The aplite dykes are rare and are less than 60 cm thick.

The granodiorite contains abundant dark-coloured xenoliths, which usually consist of subrounded masses of microdiorite up to 30 cm in diameter.

Lateritization: The laterite in the flat areas towards the eastern boundary of the area mapped has a maximum thickness of 18 m. It consists of an upper 9-m thick red ferruginous zone, containing small mottled zones up to 60 cm in diameter, which grades down into a 9-m mottled zone in which pallid and ferruginous material are irregularly mixed. Weathered granodiorite crops out beneath the laterite, but the contact is not exposed.

Sinkholes, up to 6 m deep and connected by caves and tunnels, occur in the ferruginous zone of some of the laterite outcrops.

Relationships and Age: The Auburn Complex is intrusive into Palaeozoic metamorphics and the Camboon Andesite, and is unconformably overlain by the Precipice Sandstone and Evergreen Formation. Isotopic age determinations indicate that the complex was intruded during the Upper Carboniferous and Lower Permian (A.W. Webb, pers. comm.).

The Auburn Complex is comparable with the Urannah Complex in the northern part of the Bowen Basin. The Urannah Complex occupies the axis of a southerly plunging and the Auburn Complex that of a northerly plunging anticlinal structure. The two structures form part of the same structural trend parallel to the axes of the Bowen and Mimosa Synclines.

TERTIARY INTRUSIVE ROCKS

Tabor Gabbro

The Tabor Gabbro in the northwestern part of the Eddystone Sheet area is probably Tertiary in age. It consists of a basin-shaped sill and three stocks of olivine microteschenite which intrude the Hutton Sandstone.

The sill crops out as a continuous ridge which is elliptical in plan; the northwest axis is about 8 km long and the transverse axis 6 to 7 km long. The eastern and northern limbs dip at about 5°, and the western and southern limbs at about 15°. The circular stocks to the southeast of the sill and at Mount Hopeless to the northwest are about 1.5 km across. A smaller elliptical stock crops out about 2 km southeast of Mount Hopeless.

The olivine microteschenite sill is about 45 m thick, and appears to be uniform in composition. The stock to the southeast contains pods and veins of pegmatitic teschenite, and the border facies of the stock at Mount Hopeless consists of analcite basanite.

The gabbros are probably genetically related to the Tertiary basaltic plugs and flows in the Eddystone Sheet area. The sill appears to be concordant with the Hutton Sandstone. The sandstone is unaltered even close to the sill, but silicified sandstone was observed on the flanks of the stock to the southeast. The contacts between the stocks and the Hutton Sandstone are not exposed.

Miscellaneous Basic Intrusions in the Taroom and Mundubbera Sheet Areas

The main features of the eight basic intrusions in the Taroom and Mundubbera Sheet areas are given in Table 6. The small intrusions ('Tb') on the Taroom and Mundubbera maps are regarded as pipes or feeders of the Tertiary basalt. The small fine-grained plug near Kennedy Peak consists of abundant small phenocrysts of olivine set in an intergranular groundmass of pigeonite, magnetite, and small laths of plagioclase.

The two stocks('Mi') are similar in texture. They cut the Hutton Sandstone and are certainly post-Lower Jurassic. They are considered to be Mesozoic in age, but could possibly be Tertiary.

TABLE 6: SUMMARY OF SMALL INTRUSIONS, TAROOM AND MUNDUBBERA SHEET AREAS

Location (map symbol)	Type of Intrusion	Topographic Expression	Lithology	Dimensions	Youngest Formation Intruded
1.2 km NE of Kennedy Peak, Mundubbera Sheet (Tb)	Probably volcanic neck	Good outcrop on small steep conical hill, less than 30 m high with aboriginal artifact quarry on top	Hard dark olivine basalt	Oval in plan, less than 180 m long	Evergreen Fm
Beside Hilltop homestead, Mundubbera Sheet (Tb)	Pipe-like intrusions	Red soil and poor outcrop on top of very small rise	Olivine basalt	Probably circular, 9 m across	Baralaba Coal Measures
In quarry on E side of Taroom/Wandoan road 16 km S of Taroom, Taroom Sheet (not on map)	Small dyke-like intrusions filling joint spaces, possibly above small unexposed pipe		Vesicular basalt	Less than 5 cm thick	Injune Creek Beds
6.5 km S of Cheviot homestead on Roma road, Taroom Sheet (Tb)	Unknown, probably small pipe like intrusion	Poor outcrop on very low rounded scrub-covered hill	Hard dark olivine basalt	Oval in plan, less than 420 m long	Injune Creek Beds
On Komine road just W of Taringa homestead, Taroom Sheet (Tb)	Unknown, probably small pipe-like intrusions	Few boulders only	Basalt	Unknown, probably very small	Injune Creek Beds

Location (map symbol)	Type of Intrusion	Topographic Expression	Lithology	Dimensions	Youngest Formation Intruded
3 km NW of Warndoo homestead. Taroom Sheet (Tb)	Probably volcanic neck	Good outcrop on small steep hill. 9 m high. with twin conical tops	Hard dark olivine basalt	Circular. less than 15 m across	Hutton Sst
5 km WNW of Carringal homestead. Taroom Sheet (Mi)	Small boss-like intrusion	Forms large rounded hill 60 m above surrounding country with distinctive smooth photo-pattern	Coarse-grained gabbro(?)	Circular in plan. 1.5 km across	Hutton Sst
5 km NW of Cracow township. Mundubbera Sheet (Mi)	Elongate boss 1.2 km long	Forms large rounded hill 45 m above surrounding country	Coarse-grained leucocratic gabbro(?)	1.2 x 0.4 km	Barfield Fm

Basaltic Plugs and Dykes in the Eddystone Sheet Area

About 50 Tertiary basaltic plugs and several basaltic dykes crop out in the northern half of the Eddystone Sheet area. About half the plugs lie between Mount Owen and Mount Hopeless; the others are scattered throughout the area.

The plugs form prominent conical peaks and small circular to elliptical hills ranging from about 15 m in diameter to a kilometre at Mount Ogilvie and Mount Owen. Several of the plugs rise over 300 m above the surrounding plain. Most of the plugs show vertical columnar jointing, which is well displayed near the summit of Mount Clift (Fig. 20). Horizontal columns were found near the base of several plugs. The columns are commonly from 60 cm to 1 m across, but the horizontal columns are generally smaller.

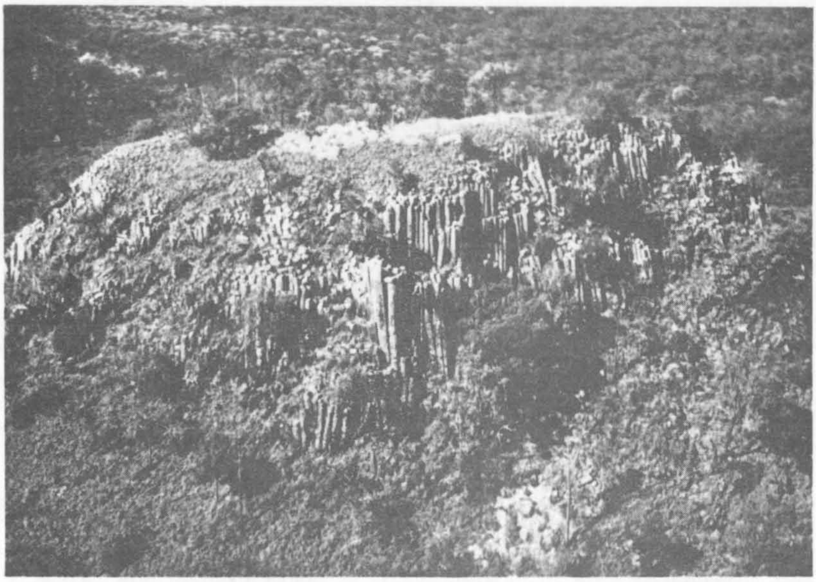

Fig. 20. Columnar basalt at Mount Clift.

Many of the plugs consist of analcite basanite composed of phenocrysts of olivine set in a fine-grained groundmass of augite, labradorite, magnetite, and interstitial analcite; orthopyroxene may also be present. The basanite of Bally Lethbridge Mountain contains nodules composed of olivine, augite, and orthopyroxene.

The close spatial relationship and similarity in composition of the Tabor Gabbro and many of the basaltic plugs, dykes, and flows indicate that they are genetically related. The plugs and dykes were probably intruded in fissures which served as feeder channels for the basalt flows. The dykes commonly trend northwest, and some of the plugs are connected by dykes. The plugs and dykes intrude sediments ranging in age from Lower Jurassic to Permian. The contacts are not exposed, but at several localities indurated and silicified sandstone was observed close to plugs and dykes.

The extrusion of the basaltic lavas was probably controlled by major faults in the pre-Jurassic rocks. The thick remnants of flood basalt in the eastern part of the Eddystone Sheet area lie close to the seismically indicated Merivale Fault. The northwesterly alignment of the plugs, dykes, and Tabor Gabbro in the northwestern part of the Eddystone Sheet is parallel to the strike of magnetic anomalies and gravity contours, and the Tertiary vulcanism was probably controlled by the structure of the basement.

STRUCTURE

The general structure of the area is shown in Figure 21. Results of gravity, aeromagnetic, and seismic surveys are presented in Figures 22, 23, and 24.

Pre-Jurassic Rocks

In the northeastern part of the area, the Permian sequence, partly intruded by the Auburn Complex, dips west at about 20°, and the Triassic sequence dips more gently in the same direction. Westerly dipping Permian-Triassic strata form the eastern limb of the Mimosa Syncline. Both seismic and aeromagnetic results indicate a major fault in the eastern limb of the syncline in pre-Jurassic rocks, but no trace of this was seen in the exposed Jurassic sequence.

The Traissic sequence appears in part of the western limb of the Mimosa Syncline. Seismic reflection surveys indicate that the western limb of the Mimosa Syncline dips at about 5° to the east, and the syncline is therefore asymmetrical, with a steeper eastern limb. The Mimosa Syncline is flanked on the west by an anticlinorium consisting of four major anticlines with sinuous northerly trending axes. Several domal culminations are present along the crests of the anticlines. The Serocold Anticline, the largest of the four folds, is markedly asymmetrical; the west limb dips at about 40° and east limb at 20°. The other three are much gentler, with lower amplitudes and only slightly steeper west limbs.

A southerly subsurface extension of the anticlinorium has been proved by seismic delineation of reflecting horizons within the Permian sequence. Seismic work has also shown that the anticlinorium is bounded on the west by the Merivale Fault, on which there is an apparent displacement of about 1050 m west side down (AGP, 1962b). The structures beneath the Jurassic rocks have not been defined immediately to the west of the fault because of a lack of seismic data.

Permian and Triassic rocks dip east off a basement ridge, the Nebine-Nogoa Ridge, which has been well defined by aeromagnetic and gravity surveys and is expressed at the surface by a small outcrop of Lower Palaeozoic gabbro near the middle of the Eddystone Sheet area. The Permian and Triassic rocks onlap the ridge, and the easterly dip, deduced by seismic work in two small areas, is probably a compactional feature. The small outcrop of basement gabbro is overlain by a veneer of Triassic(?) sediments which were probably derived from the gabbro and associated altered ultrabasic rocks.

Post-Triassic Rocks

The Lower Jurassic Precipice Sandstone rests with marked unconformity on Carboniferous (Auburn Complex), Permian, and Triassic rocks. At the surface the Precipice Sandstone has been observed resting only on Triassic, and probable Triassic, rocks. In OSL No. 2 (Hutton Creek) and Killoran No. 1,

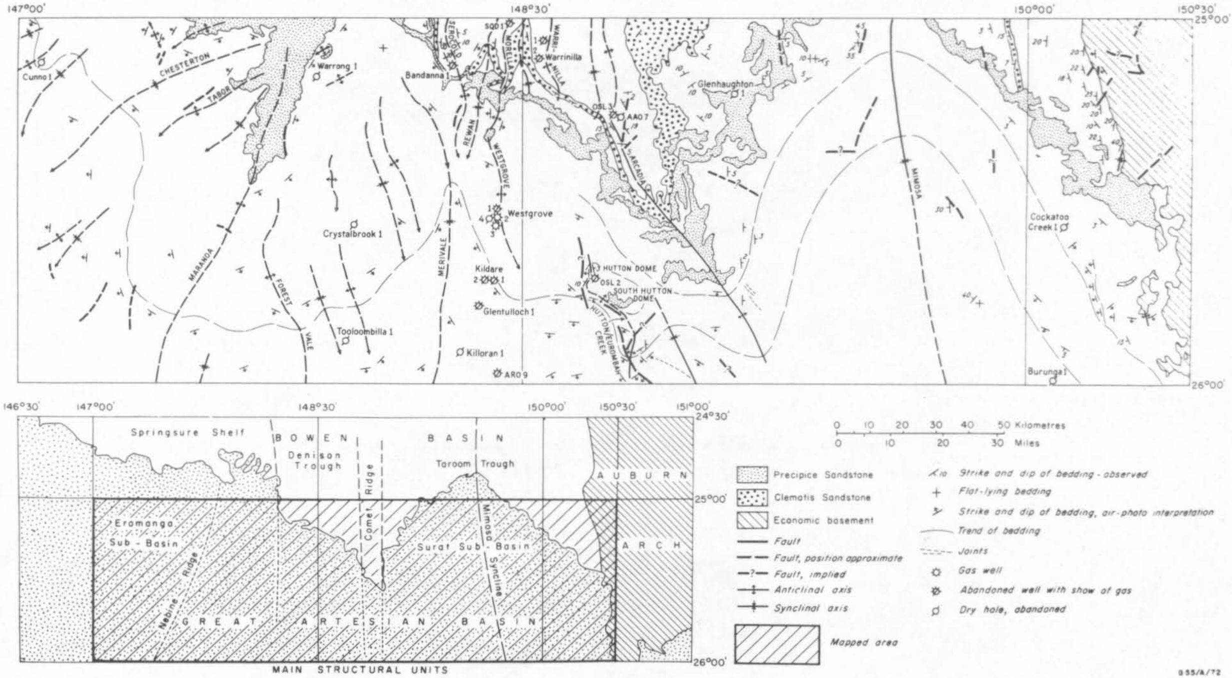

Fig. 21. Structural map.

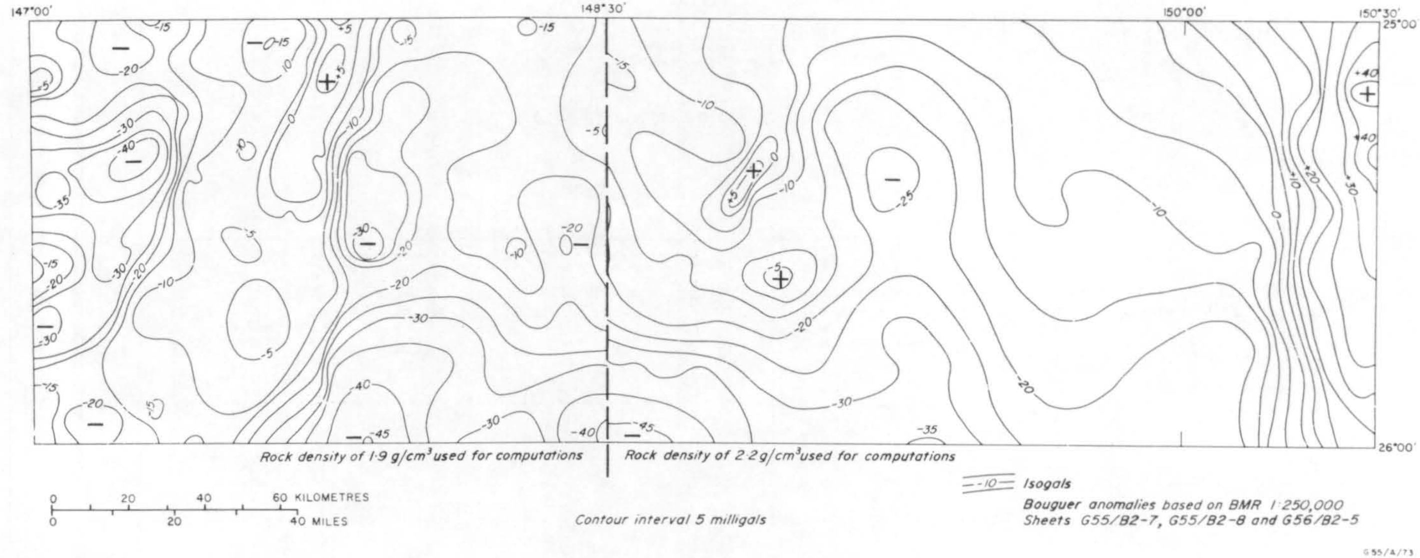

Fig. 22. Bouguer anomalies.

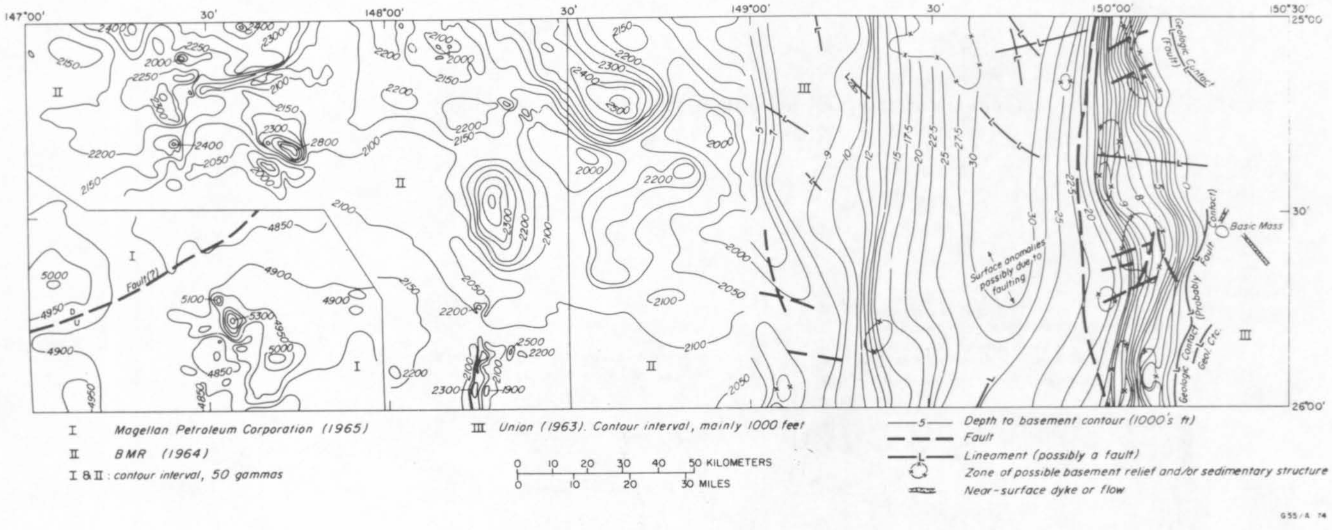

Fig. 23. Aeromagnetic map.

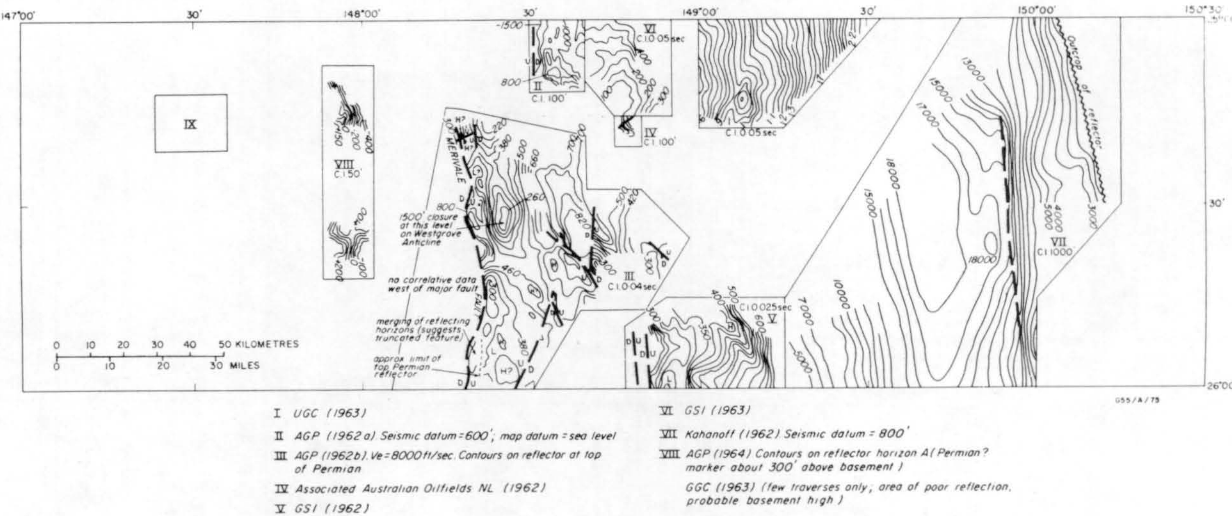

Fig. 24. Contours on seismic reflectors in the Permian sequence.

and possibly the Toolloombilla No. 1 well, the sandstone overlies Permian rocks; comparison of the logs of the three wells, and of outcrops to the north, suggests southerly thinning of the Triassic sequence. The unconformity represents uplift and erosion after folding of the Triassic sequence and before deposition of the Lower Jurassic sequence. It is possible that the unconformity has only slight angular discordance towards, and at, the base of the Triassic sequence in the Arcadia and Serocold Anticlines, but discordance is more pronounced to the south, where the Triassic sequence is either very thin or missing.

The structure of the Jurassic sequence reflects the Mimosa Syncline and the anticlinorium to the west, although dips rarely exceed 5°. The southerly plunging Maranoa Anticline reflects the buried Nebine Ridge. The south-southeasterly gentle folds between the Maranoa Anticline and the Merivale Fault and the southwesterly to west-southwesterly gentle folds west of the Nebine Ridge probably reflect folds in pre-Jurassic rocks. The gravity (Fig. 22) and aeromagnetic (Fig. 23) maps indicate concordance between pre-Jurassic basement trends and the fold axes in the Jurassic-Cretaceous sequence. The Merivale Syncline, in which Jurassic-Cretaceous sediments are involved, may be a superficial expression of the Merivale Fault.

The structure is more complicated in the Hutton Creek area, where the Jurassic sequence is folded and faulted. The Hutton/Eurombah Creek Anticline is in part crestally faulted and has at least two culminations. The anticline is represented by a fault at depth as indicated by the seismic reflection contour map (Fig. 24). This map also indicates that the simple southerly dip of the Jurassic sequence west of the Hutton/Eurombah Creek Anticline does not reflect the more complex folds in the underlying Permian sequence.

The aeromagnetic map shows basement in the axis of the Mimosa Syncline to be about 9000 m below the surface. About 5500 m of this sequence is attributable to Triassic sediments, principally the Moolayember (1650 m) and Rewan (3500 m) Formations.

This sedimentary pile is underlain in the Glenhaughton No. 1 well by probable Camboon Andesite, which is magnetic basement.

GEOLOGICAL HISTORY

Little is known of the pre-Permian history of the area. The Auburn Complex was partly emplaced during the Carboniferous, like the Urannah Complex in the northern part of the Bowen Basin. The Palaeozoic metamorphic rocks are probably remnants of an older geosynclinal sequence. The Lower Palaeozoic(?) gabbro may have been intruded at the same time as the regional metamorphism of the Anakie Metamorphics and the formation of the Nebine Ridge.

In late Carboniferous to early Permian times a thick pile of andesitic to dacitic lavas and pyroclastics was deposited in the east, and a sequence of freshwater arenite, lutite, and coal (Reids Dome Beds) was deposited in the rapidly subsiding Denison Trough, in the west. After the vulcanism in the east had subsided and the volcanic terrain has been eroded, the sea encroached over much of the area, and fluvioglacial sediments were deposited on adjacent land areas. The sea supported a coldwater Eurydesma fauna. This was followed by a period during which marine deposition continued only in the Denison Trough, and probably on the Springsure Shelf. This Lower Permian marine deposition is represented by the Cattle Creek Formation and the Ingelara Formation in the west, and by the Buffel Formation in the east; the Aldebaran Sandstone is probably a fluviatile and deltaic body of sand deposited during a marine regression in the Denison Trough.

A major change in the structural configuration of the depositional province occurred at the end of the Lower Permian. Uplift in the Denison Trough resulted in the erosion of Lower Permian sediments. The Denison Trough, the Springsure Shelf, and the Comet Ridge ceased to be distinct structural elements; transgressive marine deposition commenced in a broad downwarp (the Mimosa Trough) whose axis corresponded approximately with the axis of the Mimosa Syncline. Upper Permian sedimentation became progressively less marine as the trough was gradually isolated from the sea. Vulcanism accompanied the latter stages of Upper Permian sedimentation and fine volcanic ash, now represented by beds of bentonitic clay, was deposited over a wide area. Vulcanism ceased at the end of the Permian.

Minor tectonic movements near the close of the Permian resulted in slight unconformities between the Permian and Traissic sediments in the Serocold Anticline and Arcadia area. The basal conglomerate of the Rewan Formation in the Cracow area probably indicated uplift of the provenance area. The Mimosa Trough continued to subside during the Triassic; subsidence was more pronounced in the east, where about 5500 m of non-marine clastics were deposited.

The folding of the Permian and Triassic sequence and the emplacement of the Auburn Complex were completed by the end of the Triassic. The area was then peneplaned. The Triassic climate was arid, and most superficial rocks were silicified.

In Jurassic and early Cretaceous times gentle upward movements of the Nebine Ridge periodically separated deposition in the Eromanga Basin from deposition in the Surat Basin.

In the early Jurassic, a rejuvenated drainage from the west spread a blanket of quartz-rich sand (the Precipice Sandstone) over most of the area. At first, fluvial deposition of the Precipice Sandstone kept pace with subsidence. With continuing subsidence, deposition extended farther east, and lacustrine sediments of the Evergreen Formation were deposited as far east as the Nebine Ridge. There is evidence of at least two marine incursions into the Surat Basin during deposition of the Evergreen Formation. Lacustrine and fluvial sedimentation again predominated while the Middle Jurassic Birkhead Formation was deposited. Peat was formed in many places during deposition of the Birkhead Formation, yet there is evidence of marine influence in some of the sediments. In the Eromanga Basin, rivers flowing south deposited the Adori Sandstone along the margin of the Nebine Ridge. In the Surat Basin the lithic Springbok Sandstone was similarly deposited. The Westbourne Formation was laid down in a series of lakes which covered the whole region, although there is some evidence of minor marine incursions. Later, in Upper Jurassic and early Lower Cretaceous times, the Nebine Ridge again became effective as a barrier separating deposition in the Surat and Eromanga Basins. Alternation of fluviatile and lacustrine deposits (Gubberamunda Sandstone, Southlands Formation, Bungil Formation) characterized the Surat Basin sedimentation, while fluviatile deposition of sand (Hooray Sandstone) predominated in the Eromanga Basin. A marine transgression in Aptian time, during which the Doncaster Member was deposited, brought the period of terrestrial sedimentation to a close.

During the Tertiary, scattered beds of alluvial clay and gravel were deposited. There was also some lateritization and silicification. Basalts were extruded from fissures and vents, mainly in the west.

The gentle post-Middle Jurassic folding is largely attributed to movements on underlying faults. The Tabor Gabbro in the Eddystone Sheet area, and the gabbro at Mount Slopea in the Taroom Sheet area, were intruded in post-Middle Jurassic time.

ECONOMIC GEOLOGY

Gold

Cracow Goldfield

Gold was discovered near Cracow in payable quantities in 1931 by C. Lambert, propsecting with assistance from the Queensland Government. Many small mines operated in the early days of the goldfield. Production is given in Table 7.

TABLE 7: GOLD AND SILVER PRODUCTION, CRACOW GOLDFIELD

Period	Ore (tons)	Gold (fine oz)	Silver (oz)	Total Value (£)	Chief Producers
1932-36	110,225	94,080	7,322	790,213	GP, RP, D, LS
1937-41	357,794	130,460	111,215	1,233,372	GP, RP, RN, K
1942-46	138,377	34,610	37,236	343,165	GP, RP, K, GW
1947-51	116,417	32,415	43,183	306,834	GP, K, R, GM
1952-56	134,780	68,761	61,174	1,095,207	GP
1957-61	169,664	75,504	77,912	1,210,354	GP
1962	33,935	13,496	13,044	216,996	GP
1963	33,420	13,775	14,655	231,532	GP
1964	34,628	13,571	17,273	221,816	GP
Total	1,129,240	476,672	383,014	5,649,389	GP

Abbreviations: GP, Golden Plateau; RP, Roses Pride; K, Klondyke; D, Dawn; RN, Rome North; R, Rainbow; LS, Lamberts Surprise; GW, Golden West; GM, Golden Mile.

The Golden Plateau mine, operated by Golden Plateau NL, is the only mine still working in the Cracow Goldfield, and for many years, Golden Plateau and Mount Morgan have been the only important producers of gold in Queensland.

The Golden Plateau mine was originally worked by glory-holing but eventually it was developed as an underground mine. There are seven main haulage levels from a vertical shaft 850 feet (260 m) deep.

In 1965 the company employed from 80 to 100 men. Total production to 1965 was 476,672 oz (14,825.9 kg) of fine gold and 388,014 oz (12,068.4 kg) of silver from over 1.1 million tons of ore. Average grade is just over 8 dwt (12.5 g) per ton.

The gold deposit occurs within the Camboon Andesite, close to the contact with the Auburn Complex intrusives. Gold deposition was confined mainly to the Golden Plateau lode system, which Brooks (1965) considers to be on a fault zone between the White Hope lode on the west and the Golden Mile lode on the east (Fig. 25). Several other small lodes have also been worked. Within the Golden Plateau lode, irregular tabular ore shoots have been mined discontinuously

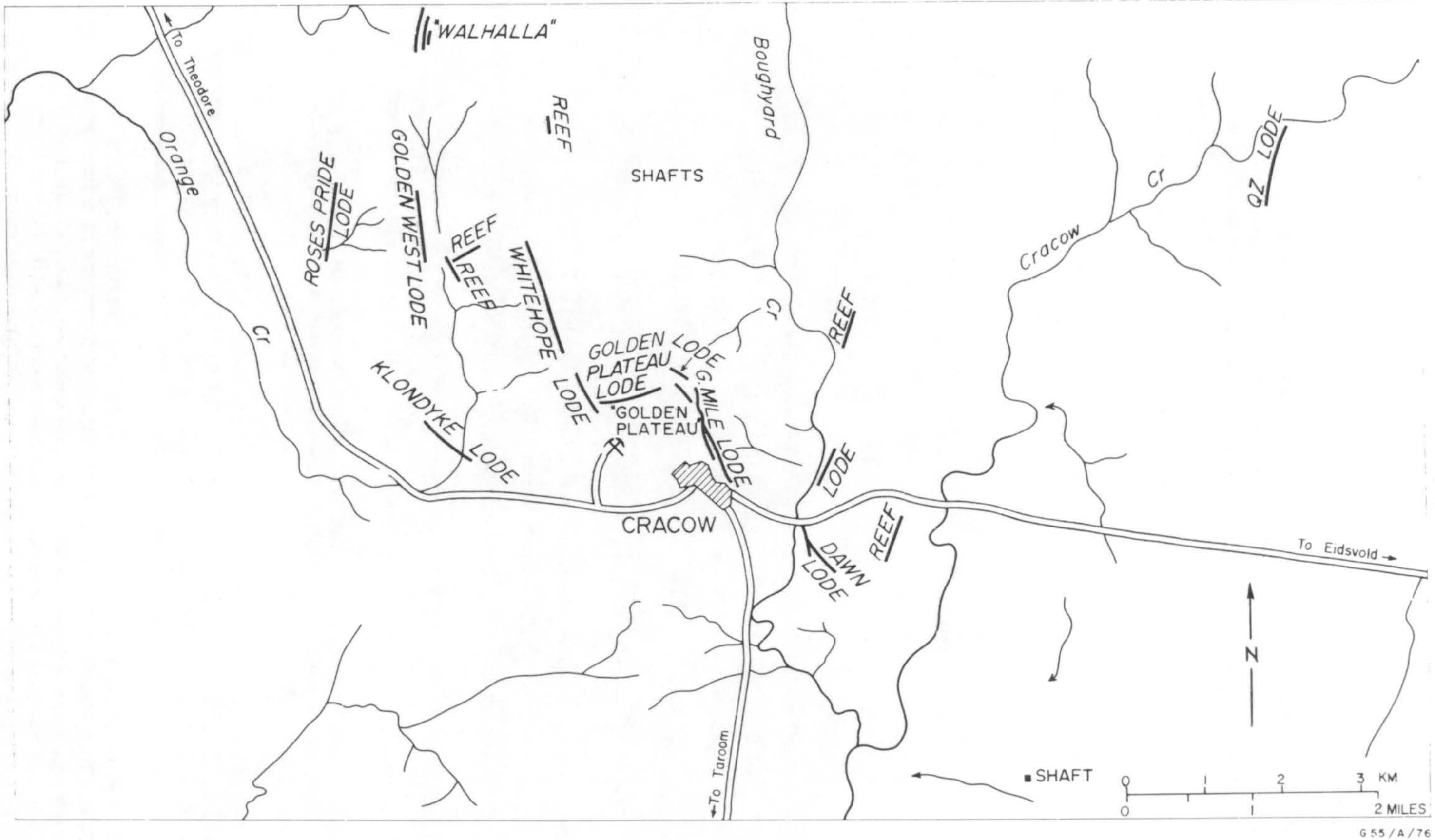

Fig. 25. Lodes in the Cracow area.

over a length of 680 m and a width of 15 m, down to a depth of 250 m. The lode system is terminated abruptly in the west by the north-northwesterly Golconda Fault (Denmead, 1946, p. 309) and on the east by a parallel fault, both of which were probably active before the lodes were emplaced as well as after.

The gold occurs as gold-silver alloy in a quartz gangue, and is seldom visible to the naked eye, even in high-grade ore. Small amounts of sphalerite, chalcopyrite, pyrite, galena, hessite, and bornite are present.

The Golden Plateau lode is regarded as a hydrothermal replacement deposit. The mineralization seems to have been localized on faults, and introduced by rhyolite dykes. Brooks (1965) notes that in nearly all ore shoots a fault plane or fault zone forms one wall. In the eastern sections of the mine the ore shoots are commonly adjacent to a rhyolite dyke.

Recent diamond drilling by the Queensland Department of Mines and Golden Plateau NL has located new ore shoots to the south of the western end of the Golden Plateau lode system. The main structural control is a fault which strikes north-northwest and dips west at 65° to 70° (J. H. Brooks, pers. comm.).

Other Areas

Gold occurs within granodiorite of the Auburn Complex at the Shepherds Camp gold prospect (Brooks, 1964). The occurrence is east of the crest of the Auburn Range, about 20 km northeast of Cracow and 5 km east of Ravenscraig homestead; it was discovered before the Cracow deposits, but recorded production is negligible. Most of the visible gold occurs in cavities and appears to represent a near-surface secondary concentration in joints.

McTaggart (1959) notes that 'some gold has been reported from the Mountain Creek area', and residents report showings of gold in quartz veins in the Red Range Creek area. Both of these areas occupy a similar geological position to the Cracow lodes, but no important deposits have been reported.

Coal

Birkhead Formation

Maranoa Colliery: In a report on drilling to test coal detected in water bores near Injune in the southwestern corner of the Taroom Sheet area, Jensen (1923) reported that 'diamond drilling has proved the district extremely prolific in small coal seams, and in carbonaceous shales, many of which are low grade oil shales, but large and consistent seams do not occur'. Two prospecting areas were granted in 1924, and three shafts were sunk. By 1932, a 100-m shaft had been sunk, and in 1963, 6408 tons of coal were produced from the Maranoa colliery, 3 km south of Injune. Coal was mined continuously for 30 years until October 1963, for a total production of 542,050 tons. Closure of the mine appears to have been due to the increased use of diesel fuel by the railways, and utilization of natural gas for power generation in Roma.

The Maranoa colliery was connected by a branch railway from Roma. The colliery workings were all on one seam which has been worked from four cross-drifts, only one of which was in use when the mine closed. The greatest thickness of the seam is 1.40 m (Mengel, 1959). The seam worked is divided into two sections by a persistent thick band of shale. The coal is weakly coking, and of high volatile bituminous rank.

Diamond drilling to assist the planning of new haulage systems and to prove reserves was requested by the owners, and 12 diamond drillholes were put down by the Queensland Mines Department in 1955. Several small seams were penetrated above the worked seam, the most persistent of which was a 60 cm seam, 1.5 to 3 m above the main seam. The deepest hole was drilled to 79.5 m and although it passed through 11 seams below the worked seam, none was sufficiently thick to warrant further testing.

The characteristics of the coal in the main seam are as follows (Hawthorne, 1956): fixed carbon, 42.6 to 51.1 percent; calorific value, 13,550 to 14,640 BTU/lb (7528-8133 kcal/kg) (Parr formula); ash content, 13.1 to 22.3 percent. (The average core recovery in the sections analysed was 97%.)

The numerous small normal faults encountered in the workings caused much loss of time and production. The maximum throw reported is 7.5 m, but most are 1 to 2 m. Hawthorne (1956) considered that the mine area was free from major faulting.

Measured reserves of 500,000 tons of workable coal with an average thickness of 1.0 m underlies an area of 38 ha. Indicated reserves of 80,000 tons in an area of 6 ha should also be available. These reserves were calculated by Hawthorne (1956) on data obtained in 1955. Table 8 gives output from 1933 to 1963.

TABLE 8: COAL PRODUCTION FROM THE MARANOA COLLIERY, INJUNE

Period	Coal (tons)	Value (£)
First production 1933		
1933-36	54,324	48,736
1937-41	92,205	93,774
1942-46	80,042	95,792
1947-51	70,201	114,141
1952-56	106,983	276,233
1957-61	113,831	365,309
1962	16,835	58,494
1963	7,650	26,778
Mine closed October 1963		
Total 1933-63	542,050.	1,079,250

Other Areas: A seam of coal in the Birkhead Formation is exposed in a creek near Oakwells homestead in the southeastern part of the Eddystone Sheet. The seam consists of 1.2 m of solid coal at the base and some thin interbedded shaly seams near the top. No other significant coal occurrences in the Birkhead Formation are known in the Eddystone Sheet area.

Little is known of the coal resources of the Birkhead Formation around Taroom. A summary of data on Queensland coalfields compiled by the Geological Survey of Queensland (1951) briefly mentions Jurassic coals in the Taroom/Wandoan area, but the deposits have not been tested.

Other Mesozoic Formations

Coal seams up to 30 cm thick are known in bores and outcrops in the Boxvale Sandstone Member near Sunrise homestead in the central part of the Eddystone Sheet area. Thin coal lenses are common in most of the Mesozoic formations throughout the area mapped.

Baralaba Coal Measures

The results of an investigation of the Baralaba Coal Measures in the western part of the Mundubbera Sheet area by the Utah Development Co. are reported by King (1961). Four seams of weakly coking coal, from 2.4 to 4.3 m thick, were located by drilling in the Monto Sheet area, just north of the Mundubbera Sheet boundary, and two seams of good-quality steam or gas coal, 3.35 and 8.5 m thick, were intersected near Kia Ora homestead in the Mundubbera Sheet area; two seams of similar coal, 3.7 and 5.8 m thick, were intersected just east of Hilltop homestead.

Blackwater Group

Several coal seams have been found in the Blackwater Group. The seams are commonly 30 to 60 cm thick, but in the east limb of the Early Storms Dome, several seams up to 1.2 m thick are associated with oil shale.

Iron Ore

Unnamed Lower Jurassic Oolite Member (Mundubbera and Taroom Sheet areas)

A bed of oolitic limonite up to 3 m thick is present in the oolite member in the Cockatoo Creek area. Ore reserves in the Dawsonvale/Cockatoo area have been estimated at 139 million tons; the thickness of the ore averages 1.42 m and the overburden 1.8 m. The average grade is 37.5 percent iron (Urquhart, 1962). An additional calculated reserve of 60 million tons is present beneath overburden averaging 6.7 m thick. The ore reserves in the Pontypool/Geddesvale/Kilbeggan area were not calculated, but the overburden has an average thickness of 4 m (Urquhart, 1962).

The beneficiation tests carried out on the ore did not give concentrates of satisfactory grade owing to the intimate association of the iron and gangue minerals, but Bollen & Gooden (1963) have suggested a direct reduction method of treatment.

Westgrove Ironstone Member (Taroom and Eddystone Sheet areas)

The Westgrove Ironstone Member is generally thinner than the oolite member, and contains less oolitic ironstone. The ironstone is most abundant in the Darkwater/Redbank area (Eddystone Sheet) and OK/Hutton Park area (Taroom Sheet). Up to 3 m of oolitic ironstone is exposed along the track from Redbank homestead to Mount Owen homestead. The thickness of the flat-lying ironstone in the OK/Hutton Park area is unknown, but overburden is thin or absent over at least 8 sq km.

Phosphate

Analyses for phosphate have been made on specimens from the Birkhead, Evergreen, and Barfield Formations. The results provide little encouragement for further search for phosphorite in this region.

Birkhead Formation

Four analyses of weathered calcareous sandstone from the Birkhead Formation show a maximum of 0.44 percent phosphorus.

Evergreen Formation

Several specimens of oolitic ironstone from the oolite member in the western part of the Mundubbera Sheet area were tested for phosphorus. The maximum phosphorus content was 0.685 percent in a specimen (T686) from the Cockatoo Creek area. Urquhart (1962) reported analyses on cores of the oolite member in the vicinity of Cockatoo Creek No. 1; the highest assay quoted, over a 30 cm section, was 2.55 percent phosphorus.

A sample of black mudstone from the Evergreen Formation just above the oolite member in BMR Mundubbera No. 29 assayed 0.6 percent P_2O_5, and a specimen of oolitic ironstone from the Westgrove Ironstone Member near Hutton Park homestead in the Taroom Sheet area contained 1.51 percent phosphorus.

Barfield Formation

Five specimens from the Barfield Formation were analysed, but only traces of phosphate were found.

Groundwater

The prospects of finding good supplies of water in the Camboon Andesite and Auburn Complex are poor, but moderate supplies can be obtained from shallow bores in fractured zones and in the overlying alluvium.

The Buffel and Oxtrack Formations have yielded good supplies where there is sufficient fracture or solution porosity. Of the remaining Permian units, only the basal part of the Gyranda Formation, or the sandstone of the Baralaba Coal Measures, offers any hope for plentiful supplies. The Rewan Formation is generally tight, but the Clematis Sandstone and Moolayember Formation should yield good supplies of water suitable for stock.

The lower part of the Precipice Sandstone is a good aquifer and plentiful supplies of potable subartesian and artesian water can be obtained in most areas. Most of the bores are subartesian, but good artesian supplies are obtained in the Yoorooga/Kintore/Glebe area at depths of 210 to 300 m.

Springs are common in creeks cutting the Precipice Sandstone, and many of the creeks are perennial downstream from the springs. The Dawson River, Hutton Creek, Cockatoo Creek, and many smaller creeks are fed by springs. Mound springs occur in the Hutton Creek area, northeast of Injune, and are common on Pigface Flat. They are usually circular in plan, and covered with a spongy mat of black mud and reeds. The spring water is commonly dark-coloured, but a sample tested in the laboratory showed no trace of hydrocarbons. The mounds range from 15 cm to 9 m in diameter. Most of the springs of Pigface Flat occur close to a small fault along the axis of the Hutton/Eurombah Creek Anticline. The artesian water probably comes from porous beds in the Precipice Sandstone on the flank of the South Hutton Dome. Ball (1918) has described a mound spring at Crystalbrook.

The Evergreen Formation is, in general, an aquiclude. The Boxvale Sandstone Member is a useful aquifer, and yields good supplies of subartesian water in much of the Eddystone Sheet area and western part of the Taroom Sheet area. Limited artesian supplies are obtained from the Evergreen Formation along the Hutton/Eurombah Creek Anticline, and one bore in Boxvale Sandstone, west of the Hutton Dome, yields artesian water from a depth of 9 m.

The Hutton Sandstone is not a good aquifer in the Taroom and Mundubbera Sheet areas because the yield is variable and the water is commonly brackish; in places it is unfit for stock. However, in the Eddystone Sheet area, it is the best source of supply (see Table 9). Farther west, in the northeastern part of the

TABLE 9: WATER BORES IN THE EDDYSTONE SHEET AREA

Probable Aquifer	Status				Supply (gph)								Quality								Total No	
	Reg.*		Unreg +		0-500		500-1000		1000		Unknown		Good, v good, fresh, potable		Stock		Salty		Unknown			
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Alluvium (Qa)	-	-	1	100	1	100	-	-	-	-	-	-	1	100	-	-	-	-	-	-	1	0.5
Gubberamunda Sst (Jug)	-	-	1	100	1	100	-	-	-	-	-	-	1	100	-	-	-	-	-	-	1	0.5
Injune Creek Gp (Ji)	7	44	9	56	7	44	6	38	2	12	1	6	5	31	0	0	1	6	10	63	16	7.0
Hutton Sst (Jlh)	36	40	53	60	7	8	41	46	20	22	21	24	32	36	3	3	1	1	53	60	89	41.0
Boxvale Sst (Jlb)	7	19	31	81	-	-	15	39	14	37	9	24	16	42	1	3	-	-	21	55	38	18.0
Precipice Sst (Jlp)	7	23	23	77	5	17	9	30	3	10	13	43	8	27	1	3	-	-	21	70	30	14.0
Unknown	8	20	32	80	3	7	16	40	1	3	20	50	13	32	1	3	-	-	26	65	40	19.0
Total	65	30	150	70	24	11	87	40	19	64	30	30	76	35	6	3	2	1	131	61	215	100

*Registered. +Unregistered

Eromanga Basin, it is also the main aquifer (R.R. Vine, pers. comm.). Because of the thick porous sandy soil developed on the Hutton Sandstone surface water is not plentiful.

The Injune Creek Group provides few useful aquifers. Water is commonly encountered near coal seams, but it is generally brackish and unfit for stock. The clay soil on the group is suitable for earth dams.

Springs are common around the base of many of the Tertiary basalt cappings. The lakes high on the side of Mount Hutton are supplied by water seeping out of the basalt capping. The Merivale River and other creeks are fed from springs from the basalts along the Great Dividing Range in the northeastern part of the Eddystone Sheet area.

The alluvium in most of the stream beds contains a fair supply of good-quality shallow groundwater.

Production from registered and unregistered bores in the Eddystone Sheet area is presented in Table 9. The Hutton, Boxvale, and Precipice Sandstones appear from these statistics to be good aquifers. The aquifers in the Boxvale and Hutton Sandstones have considerably higher yields than those in the Precipice Sandstone. The Gubberamunda Sandstone covers only a small area in the Eddystone Sheet area and insufficient data are available to assess its potential as an aquifer.

Oil and Gas

The results of exploratory drilling for oil and gas are summarized in Table 1. Wells have been drilled in the Denison Trough, the Springsure Shelf, the Mimosa Trough, and the Surat Basin (Figs 15, 16). Substantial quantities of gas have been discovered in the Westgrove No. 2 and No. 3, Glentulloch No. 1, and Warrinilla No. 1 and No. 2 wells; the most productive intervals are the Lower Permian Aldebaran Sandstone, and a sandstone sequence at the top of the Upper Permian Peawaddy Formation. No significant shows of hydrocarbons have been found in post-Permian rocks within the area mapped.

Evans (1962) recorded the presence of marine microfossils in beds now recognized as the Evergreen Formation, and he has suggested that the hydrocarbons in the Surat Basin could be derived from Mesozoic sediments. De Jersey (1965) has presented evidence suggesting that the oil in the Jurassic sediments at Moonie, on the southwestern flank of the Surat Basin, has its source in the Evergreen Formation, rather than the Permian sequences. Furthermore, he suggested that the Jurassic sediments may contain the only source of petroleum so far discovered in the Surat and Bowen Basins. These suggestions are based on determinations of spores in oil samples, and observations by Evans (1963) on the quality of spore preservation and of carbon ratios throughout the Permian to Jurassic sequence. The Evergreen Formation is probably only partly marine.

The source of the gas discovered in the Permian sandstones is possibly the dark lutites in the marine Cattle Creek and Ingelara Formations of the Denison Trough, the partly marine Black Alley Shale, and the marine Barfield Formation of the Mimosa Trough. The non-marine shales in the Reids Dome Beds and Blackwater Group cannot be dismissed as potential source beds because some petroleum is known to be of continental origin (Hedberg, 1964); also, the Blackwater Group contains oil shale.

Apart from the Aldebaran Sandstone and sandstone in the Peawaddy Formation, both of which have produced gas, the Clematis, Precipice, Boxvale, Hutton, and Gubberamunda Sandstones include potential reservoirs. The Adori and Hooray

Sandstones in the Eromanga Basin are also potential reservoirs. Little is known about the variation in porosity in these units, but drilling in the Precipice Sandstone to the south has revealed considerable variation.

Several exposed and buried domes in the Denison and Mimosa Troughs (Figs 16, 19) have been drilled with varying success. On the Springsure Shelf the Warrong No. 1, Crystalbrook No. 1, and Tooloombilla No. 1 wells were drilled to test the possibility of finding hydrocarbons where the Permian and Triassic sandstones wedge out against the Nebine Ridge.

The prospects of finding hydrocarbons in the Jurassic and Cretaceous sequences are limited by the lack of folding, and by the movement of artesian water through the sandstones. Closures are possibly present in the Injune area, over faults in the Permian rocks. The Hutton/Eurombah Creek Anticline may enclose Mesozoic sandstones with good reservoir properties. The possibility of hydrodynamic entrapment of hydrocarbons in the Mesozoic sequence cannot be excluded.

A reported oil seep in the Carnarvon Gorge was found to be due to inorganic staining or algae growing around a small water seepage.

Bentonite

Several beds of bentonitic clay are present in the Black Alley Shale. They are commonly yellowish green and rarely more than 30 cm thick. They contain glassy shards and are commonly associated with tuff and black shale. Thompson & Duff (1965) have shown that some of the bentonitic clays are suitable for use in drilling muds, and the Black Alley Shale is now being prospected for bentonite.

Road Metal and Aggregate

None of the small basaltic intrusions in the Mundubbera and Taroom Sheet areas are big enough to be worth quarrying for road metal or aggregate. The basalt near Acacia homestead (Mundubbera Sheet) could be used in the Theodore district, and the gabbro at Mount Slopea (Taroom Sheet) is large enough to be quarried for road metal or aggregate. In the Eddystone Sheet area, there may be places close to the Womblebank/Glentulloch road where quarries could be developed to work the basalt capping Mount Hutton, and the basalt hill 5 km west-northwest of Killoran homestead is also a possible quarry site. In the north the most promising quarry sites for basalt are Mount Ogilvie, Ogilvie Knob, and Mount Howe. Some of the basaltic and gabbroic intrusions in the Mount Owen/Barngo area could probably be exploited for local use.

Limestone

The massive fossiliferous Permian limestone around Cracow was used in the construction of the Binda Weir. Thin beds of impure limestone are known to occur in the Birkhead Formation near Injune, but the prospect of locating workable deposits seems to be remote. Both the Oxtrack and Buffel Formations could supply a large quantity of limestone, but the quality is likely to vary appreciably along strike.

Clay

Commercial clay deposits may be present in the Evergreen Formation, Injune Creek Group, Gubberamunda Sandstone, Bungil Formation, and some of the Tertiary sediments.

Whitehouse (1952) noted that the clays in the Injune Creek Beds are generally calcareous and non-kaolinitic, but the white clays in the lower part of the Evergreen Formation are kaolinitic.

Beds of uniform white claystone up to 1.5 m thick crop out in the Bungil Formation and Gubberamunda Sandstone in the southeastern part of the Eddystone Sheet area.

The most likely source of Tertiary clay is the sediments on Gyranda Station near Cracow. The clay is at least 18 m thick in one place, but its extent and quality are unknown.

Oil Shale

There are numerous reports of oil shale and kerosene shale in the Birkhead Formation in the Injune area. Several distillation tests have been carried out and the highest yield of crude oil was 225 l per ton.

The occurrence of oil shale in the Blackwater Group in the east limb of the Early Storms Dome was first reported by Jensen (1926, pp. 141, 160). It was re-examined by Denmead (1943), who reported that the seam was of relatively poor quality, probably lenticular, and of restricted distribution; the observed thickness was 69 cm. Denmead (1943) reported a yield of 135 l of crude oil per ton. Beasley (1945, p. 128) described the shale as a low-grade dull black torbanite.

Asbestos

The occurrence of asbestos at 'Eddystone' has been known for many years, and was first reported on by Dunstan (1920). The asbestos occurs in an inlier of gabbro and ultrabasic rocks about 15 km west of Darkwater homestead. Local inhabitants report that the deposits were worked many years ago, but no production is officially recorded. Some brittle slip-fibre asbestos of very poor quality was seen near shallow pits.

Manganese

Samples of wad and sandstone impregnated with manganese oxides, from two localities west of Bally Lethbridge in the Eddystone Sheet area, were submitted to the Geological Survey of Queensland in 1952. One of the samples contained the following:

	%
Mn	38.9
BaO	8.5
SiO_2	6.6
Co	2.4
Fe	1.8
Cu	0.6
Ni	0.2

The occurrence was not visited, but is probably in the Boxvale Sandstone Member.

Opal

Potch opal occurs in the Hutton Sandstone near Kilbeggan homestead in the Mundubbera Sheet area, but no precious opal has been found. Jensen (1926, p. 58) mentions opal matrix in the basalt at Maintop/Mount Hutton in the Eddystone Sheet area.

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APPENDIX 1

MINERAGRAPHIC INVESTIGATION OF A FERRUGINOUS OOLITE FROM THE MUNDUBBERA SHEET AREA

by

I.R. Pontifex*

The sample is essentially a homogeneous, semi-indurated aggregate of limonite oolites. The dark brown irregular silicified bands are roughly parallel throughout; they range from 0.5 to 3 mm in thickness. Thin siliceous veins occur at random through the rock.

The entire section consists of an aggregate of limonite oolites of elliptical and spherical shape; they range from 0.3 to 0.8 mm in diameter, but average about 0.6 mm across. The oolites are composed mainly of limonite with a concentric structure. The structure is poorly defined because of alteration and leaching. The outer crust of each oolite is generally not present in its entirety, but where it is intact it is well defined; it consists essentially of hydrated iron oxide and attains a maximum thickness of 0.015 mm.

The leach cavities within the oolites are commonly lined by finely crystalline siliceous material and amorphous iron oxide. The interstices between the oolites are also filled with siliceous material and hydrated iron oxides, which form a weak binding cement. These components have been distributed through the aggregate after the formation of the oolites, probably by means of supergene agencies.

In the dark brown silicified bands the oolites have been thoroughly impregnated and almost completely replaced by extremely fine cryptocrystalline silica simulating iron-rich jasper.

Throughout the aggregate, exsolution-type needles of hematite occur in minor abundance in some oolites; they are about 0.003 mm wide and extend across the diameter of the host oolite. These needles have a generalized common orientation almost perpendicular to the siliceous bands.

A few fine grains of pyrite, 0.002 mm across, are distributed at random through the aggregate.

The oolites may have been deposited originally as limonite pellets, but it is more probable that they represent a completely oxidized oolite deposit of pre-existing iron minerals such as hematite, magnetite, or chamosite.

The oolite is estimated to contain about 45 percent iron.

* Formerly of the Bureau of Mineral Resources

APPENDIX 2

PERMIAN MARINE MACROFOSSILS FROM THE MUNDUBBERA AND MONTO SHEET AREAS*

by

J.M. Dickins

INTRODUCTION

The Permian marine faunas from the Mundubbera and Monto Sheet areas in the southeastern part of the Bowen Basin have aroused considerable interest, but correlation with other parts of the Bowen Basin has presented many difficulties, partly because of discontinuity of outcrop.

In recent years, Hill (1950) has described Productinae from near Cracow homestead, Maxwell (1954) has described Strophalosia from the area, and Campbell (1961), species of Ingelarella and Notospirifer.

Some of the fossils recorded here were collected early in 1963, before the main collection was made, and the help of Dr P.F. Howard and Mr R. Appleby of Utah Development Co., who made this possible, is acknowledged. I am also grateful to Dr R.E. Wass, now at the Department of Geology in the University of Sydney, for discussion on the problems of this area and for access to his Honours Thesis on the Cracow area, and to Dr J.F. Dear of the Geological Survey of Queensland, who is mapping the Permian rocks of the Monto Sheet area. Dr Dear has supplied stratigraphical and palaeontological information and has kindly helped in collecting the reference material from the Monto area which is listed in this Report.

The identifications are standardized with those used in other reports on fossils from the Bowen Basin. Many of the species identified are illustrated in the Permian Index Fossils of Queensland (Hill & Woods, 1964), and the names, in the main, correspond with those used in the Index.

CONCLUSIONS AND CORRELATIONS

The occurrence of the species is shown in the accompanying distribution chart, and the correlation of the Permian sequence and its relationship with underlying and overlying formations is shown in the table. This table was also presented by Dickins (in Mollan, Dickins, Exon, & Kirkegaard, 1969).

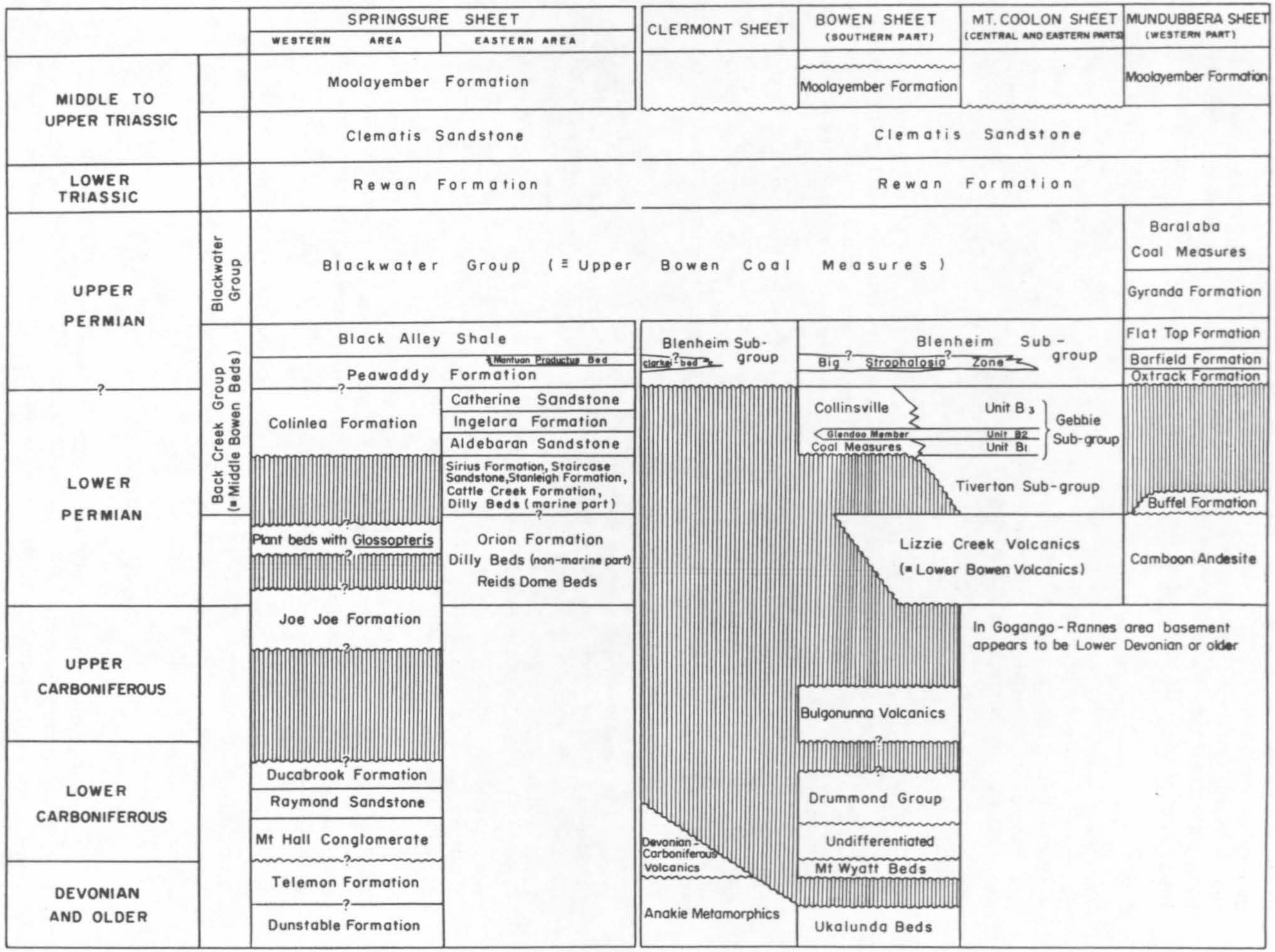
Two quite distinctive faunas are found in the marine Permian of the western part of the Mundubbera Sheet area. These two faunas are also found in the western part of the Monto Sheet area, immediately to the north.

The older fauna, found in the Buffel Formation, appears to be a Fauna II.** Like Fauna II elsewhere, it contains Eurydesma, Deltopecten, Anidanthus, Taeniothaerus, and Neospirifer (Grantonia), which are not known above Fauna II

* The Permian marine fossils on the southern extension of the Springsure-Serocold Anticline in the northeastern part of the Eddystone Sheet area are listed in the Report on the Springsure Sheet (Dickins in Mollan et al., 1969).

**Faunas I, II, III, and IV, in this stratigraphic order, were first recognized in the northern part of the basin (Dickins, 1964; Dickins, Malone, & Jensen, 1964). This scheme has been subsequently applied in other parts of the basin and is now employed for the southern part.

CORRELATION OF PERMIAN FORMATIONS OF BOWEN BASIN AND RELATIONSHIPS WITH OVERLYING AND UNDERLYING UNITS



M(S)31a

in the Bowen Basin. It contains, as well, distinctive species of wider ranging genera or subgenera. Only a single species found in the older fauna is known in the overlying Oxtrack Formation. Species characteristic of Fauna I have not so far been identified and, therefore, the occurrence of Keeneia suggests that only the lower part of the beds with Fauna II (Unit A of Dickins et al., 1964) is represented.

The younger fauna is found in the Oxtrack, Barfield, and Flat Top Formations. The assemblages in the three formations are closely related and some of the differences reflect different environments and conditions of accumulation. For example Parallelodon sp. nov. B is found in the Oxtrack Formation. It is not recorded from the dark fine-grained sediments of the Barfield Formation but reappears in the Barfield/Flat Top transition beds. On the other hand, Glyptoleda, a mud-burrowing form, is found in the Barfield Formation but not in the other two formations.

The presence of Fauna IV in the Oxtrack, Barfield, and Flat Top Formations is shown particularly by the occurrence of Parallelodon sp. nov. B., Terrakea solida, Strophalosia ovalis, and Neospirifer sp. B in the Oxtrack Formation, Myonia carinata, Platyteichum coniforme, Terrakea solida, Neospirifer sp. B, and Licharewia sp. nov. in the Barfield Formation, and Parallelodon sp. nov. B, Myonia carinata, Atomodesma bisulcatum, Schizodus sp. nov. C, Terrakea solida, Strophalosia ovalis, Neospirifer sp. B, Licharewia sp. nov., Notospirifer minutus, and Streptorhynchus pelicanensis in the top part of the Barfield Formation and the Flat Top Formation. This is consistent with the conclusion made by J.F. Dear that the Barfield Formation contains Fauna IV (pers. comm.).

The details of correlation with other parts of the Bowen Basin are discussed in later sections, but it appears that the Oxtrack Formation is close to the base of the beds with Fauna IV (Blenheim Subgroup = Unit C of Dickins et al., 1964) and is younger that the Ingelara Formation of the Springsure area. The upper part of the Barfield Formation and the lower part of the Flat Top Formation are equivalent, in a general way, to the Mantuan Productus Bed and to the stratigraphical interval containing the Big Strophalosia Zone and the Streptorhynchus pelicanensis Bed in the northern part of the basin.

No indication of Fauna III from the Gebbie Subgroup (Unit B) has been found in the western parts of the Mundubbera and Monto areas, and the Gebbie Subgroup and most of the Tiverton Subgroup (Unit A) of the other parts of the basin may be represented by an hiatus. This hiatus is possibly both depositional and erosional.

Evidence for the age of the faunas is discussed elsewhere (Dickins, in press). The Buffel Formation is of Lower Permian (late Sakmarian or early Artinskian) age and the Oxtrack, Barfield, and Flat Top Formations are probably of lower Upper Permian (Kazanian) age.

ENVIRONMENT OF DEPOSITION

Most of the sequence with the younger fauna (Fauna IV) was apparently laid down in an offshore environment. This is suggested by a lack of coarse land-derived detritus, found in equivalent formations elsewhere in the basin, and the fineness of the sediments, the development of limestones in the Oxtrack Formation, and the calcareous nature of the upper part of the Barfield Formation and lower part of the Flat Top Formation. It is suggested also by the poor representation of robust shelly fossils characteristic of the turbulent marginal area of the sea, and in the Oxtrack Formation by large numbers of corals, crinoids, and delicate bryozoans which might be expected to live in relatively calm bottom water. The Barfield Formation is particularly characterized by mud-burrowing pelecypods.

The Buffel Formation on the other hand has large numbers of robust shells. In places it has many fragments of conglomerate size and lacks any indication of turbidity current action; it was probably laid down closer to the shore. The development of limestone here may indicate a restricted supply of land-derived clastic material. Much of the coarse material in the Buffel Formation seems to be derived from the underlying Camboon Andesite. As this detritus is not found in the younger marine formations, the Camboon Andesite was apparently covered by the sea and was not being actively eroded in this area when the Oxtrack, Barfield, and Flat Top Formations were being laid down.

IDENTIFICATIONS

MUNDUBBERA AREA

BUFFEL FORMATION

T1. Mt Ox, 3 km north of Cracow/Theodore road crossing of Oxtrack Creek.

Brachiopods

Cancrinella cf. farleyensis (Etheridge & Dun, 1909)
Anidanthus springsurensis (Booker, 1932)
Strophalosia preovalis Maxwell, 1954
Neospirifer (Grantonia) cf. hobartensis (Brown, 1953)
Neospirifer sp. A.
Ingelarella cf. ovata Campbell, 1961 (sulcus wide in some specimens as in I. plana and, in some, adminicula in pedicle valve long and parallel)
Pseudosyrinx sp. (high area as in species from Fauna II and possibly Ingelara Formation. Surface with striations and pustules)
Spiriferellina sp. (punctate, with septum in pedicle valve)

T118. 1.3 km west-northwest of Cracow homestead.

Pelecypods

Eurydesma hobartense (Johnstone, 1887)
Deltopecten limaeformis (Morris, 1845) (perhaps costae more numerous than typical)

Gastropods

Keeneia sp. (these specimens show considerable variation in the shape of the whorl cross-section and the height of the spire. One shows faint revolving ornament. A shallow external umbilicus is present but none have an open umbilicus)
Peruvispira sp. ind. (whorls relatively rounded, spire of moderate height)

Indeterminate pleurotomarians

Brachiopods

Cancrinella farleyensis (Etheridge & Dun, 1909)
Terrakea pollex Hill, 1950
Terrakea sp. (as at locality B686 in southern part of Bowen Sheet area)
Anidanthus springsurensis (Booker, 1932)
Strophalosia preovalis Maxwell, 1954
Taeniothaerus sp. (close to T. subquadratus sensu stricto of Hill, 1950)*

*The specimens of Taeniothaerus from the Mundubbera area have been compared with those from the Springsure Sheet area (Sp720 and Sp732 from the Eurydesma Limestone) and with those from the Homevale area and from the Mount Coolon Sheet area (MC485). Considerable variation is shown in width, development of the umbonal shoulders, and length of trail, as indicated by Hill

Lissochonetes sp.
Neospirifer (Grantonia) cf. hobartensis (Brown, 1953)
Ingelarella ovata Campbell, 1961 (some specimens approach I. plana in shape)
Ingelarella denmeadi Campbell, 1961

Bryozoans

Large branching forms

T133a. 0.4 km west of Roses Pride mine.

Pelecypods

Eurydesma hobartense (Johnson, 1887)
Deltopecten cf. limaeformis (Morris, 1845)

Brachiopods

Anidanthus springsurensis (Booker, 1932)
Strophalosia preovalis Maxwell, 1954
Taeniothaerus sp. (mainly T. subquadratus var. cracowensis Hill, 1950)
Neospirifer (Grantonia) cf. hobartensis (Brown, 1953)
Notospirifer hillae Campbell, 1961
Streptorhynchus sp. (similar or same as species found at Sp720 and Sp732 from Eurydesma Limestone of Springsure area)

T201. On ridge, 0.8 km northwest of Roses Pride mine.

Gastropods

Keeneia? sp. - these specimens are higher-spired than those at T118. They also lack an umbilicus. The whorl cross-section varies from oval to distinctly carinate.

Brachiopods

Anidanthus springsurensis (Booker, 1932)

Fenestellid bryozoans

T205. 2.1 km northwest of Cracow homestead.

Brachiopods

Taeniothaerus sp. (close to T. subquadratus s.s. of Hill, 1950)

(1950). At Cracow and in one horizon at Homevale, forms with well developed umbonal shoulders and long trails predominate. Hill has referred these to T. subquadratus var. cracowensis. In other horizons at Homevale, however, forms can be referred to T. subquadratus var. acanthophorus Fletcher, 1945, and T. subquadratus s.s. These differences seem to represent different ecological and accumulation environments rather than different geographical races, and in these circumstances it seems better to refer the different groups to different varieties rather than to subspecies or species. Considerable variation is shown in the development of the cardinal area of the pedicle valve and it is doubtful whether the differences from Aulosteges are sufficient to warrant even subgeneric separation.

Relationships

The Buffel Formation was originally included by Derrington & Morgan (in Hill & Denmead, 1960, p. 205) in the Oxtrack Formation. Dorothy Hill, in unpublished work, suggested that the Oxtrack Formation of Derrington & Morgan contained two distinctive faunas. The Buffel Formation was first mapped separately by Wass (1965). Wass also showed that it contained a distinct fauna, older than that of the Oxtrack Formation, as now restricted. These conclusions are confirmed by the work of J. F. Dear on the Monto Sheet and by the present examination. Except for Neospirifer sp. A, none of the species definitely identified from the Buffel Formation are found in the Oxtrack or higher formations in the Mundubbera or Monto areas. With a few exceptions, all the species are found only in Faunas I and II. T118, T133a, T201, and possibly T205 appear to be in a similar stratigraphical position, low in the Buffel Formation. Species characteristic of Fauna I are absent, but Keeneia sp. suggests the Buffel Formation contains an early Fauna II, that is, the Buffel Formation is in a stratigraphical position similar to the Yatton Limestone which is at the base of the Middle Bowen Beds (Back Creek Group) of the Saint Lawrence area. Lithologically the Buffel Formation resembles the Yatton Limestone in containing dark coquinitic limestone with much andesitic detritus. The significance of I. denmeadi at T118 is not clear, as the species is not known elsewhere.

T1, which may be slightly higher stratigraphically than the other localities from the Buffel Formation, has only a relatively few species, but clearly these represent a Fauna II. The Oxtrack Formation contains Fauna IV, so that most of the basal unit of the Back Creek Group to the north (Tiverton Subgroup), as well as the Gebbie Subgroup, is possibly missing in the Mundubbera area: in places the Blenheim Subgroup with Fauna IV rests directly on the lower part of Tiverton Subgroup.

OXTRACK FORMATION

T23. 0.8 km northeast of Cracow/Theodore road crossing of Oxtrack Creek.

Brachiopods

Terrakea cf. solida (Etheridge & Dun, 1909)
Strophalosia clarkei var. minima Maxwell, 1954
Neospirifer sp. B
Ingelarella sp. ind.

T24. 1 km southeast of Cracow/Theodore road crossing of Oxtrack Creek.

Brachiopods

Terrakea solida (Etheridge & Dun, 1909)
Ingelarella mantuanensis Campbell, 1960

Branching bryozoans

Angular pebbles of fine-grained greenish cherty material up to 2.5 cm across

T126. 4.5 km southwest of Cracow homestead.

Brachiopods

Ingelarella mantuanensis Campbell, 1960

T133b. 0.4 km west of Roses Pride mine, about 45 m west of T133a (note the difference in faunas between the two: T133a and T133b are separated by an area of non-outcrop).

Brachiopods

Terrakea solida (Etherdige & Dun, 1909)
Strophalosia clarkei (Etheridge Snr, 1872)
Strophalosia clarkei var. minima Maxwell, 1954
Neospirifer sp. B
Ingelarella mantuanensis Campbell, 1960

Branching bryozoans

Single corals

Crinoid stems

T134. 4 km southwest of Cracow homestead.

Pelecypods

Parallelodon sp. nov. B (Fauna IV type)
Conocardium sp.

Brachiopods

Terrakea solida (Etheridge & Dun, 1909)

Bryozoans

T135a. 5 km southwest of Cracow homestead, on west limb of syncline.

Pelecypods

Parallelodon sp. nov. B
Volsellina? mytiliformis (Etheridge Jnr, 1892)
Atomodesma (Aphanaia) sp.
Streblopteria sp.

Brachiopods

Cancrinella cf. magniplica Campbell, 1953*
Strophalosia clarkei var. minima Maxwell, 1954
Strophalosia ovalis Maxwell, 1954
Neospirifer sp. ind.
Ingelarella mantuanensis Campbell, 1960
Dielasmatid

T135b. 5 km southwest of Cracow homestead, on east limb of syncline, about 100 m from 135a.

Pelecypods

Volsellina? mytiliformis (Etheridge Jnr, 1892).
Atomodesma (Aphanaia) sp.

* R.E.Wass, in his unpublished thesis, considers this to be distinct specifically from C. magniplica from the Ingelara Formation. In this Report, the species is referred to provisionally as C. cf. magniplica - it is found in the Oxtrack, Barfield, and Flat Top Formations of the Mundubbera and Monto Sheet areas.

Streblopteria sp.
Plagiostoma? sp. nov.

Gastropods

Peruvispira sp.

Brachiopods

Terrakea cf. solida
Strophalosia clarkei var. minima
Neospirifer sp. B
Ingelarella mantuanensis

Fenestellid bryozoans

Single corals

Crinoid ossicles

T152. 2.4 km north-northwest of Cracow/Theodore road crossing of Oxtrack Creek.

Pelecypods

Volsellina? mytiliformis (Etheridge Jnr, 1892)

Brachiopods

Terrakea solida (Etheridge & Dun, 1909)
Neospirifer sp. B

Relationships

The Oxtrack Formation is a persistent unit found in the Mundubbera and Monto areas below the Barfield Formation. In some places it overlies the Buffel Formation, but more commonly it lies directly on the Camboon Andesite. In the outcrop, it has been recognized only along the eastern side of the Bowen Basin and is not known to persist farther north than the Thuriba area, in the southern part of the Duaringa Sheet area.

Parallelodon sp. nov. B, Terrakea solida, Strophalosia ovalis, and Neospirifer sp. B indicate that the fauna of the Oxtrack Formation represents a Fauna IV. None of these species have been found in Fauna III. Parallelodon sp. nov. B and Neospirifer sp. B are particularly characteristic of the Big Strophalosia Zone and overlying beds, but probably Terrakea solida and Strophalosia ovalis occur lower down, in the basal part of the Blenheim Subgroup (the material unfortunately isn't quite satisfactory for definite identification).

In the Springsure area, the four species seem to be absent from the outcrop of the Ingelara Formation and Catherine Sandstone as restricted by Mollan, Kirkegaard, Exon, & Dickins (1964), and have not been found below the Mantuan Productus Bed. In the Glentulloch No. 1 well, however, Terrakea solida and Strophalosia ovalis are identified by Dear (1962), below the level of the Mantuan Productus Bed in a stratigraphical position regarded as equivalent to the Oxtrack Formation (see Dickins in Mollan et al., 1969) and also later discussion.

The fauna of the Oxtrack Formation is found essentially unchanged in the overlying Barfield and Flat Top Formations. In the Barfield Formation additional species appear, so that the fauna appears closer to that of the Ingelara Formation, but this is apparently ecological, as, with the possible exception of Cancrinella magniplica, all the species which suggests relationship with the Ingelara Formation are known to occur in both Fauna III and Fauna IV (see Dickins, 1964: in press: Dickins in Mollan et al., 1969). If indeed C. magniplica occurs in the Oxtrack Formation and above, the evidence considered in this Report suggests that it also ranges from Fauna III into Fauna IV.

BARFIELD FORMATION

T31b. 5.3 km south of The Braes homestead and about 3 km south of Back Creek.

Pelecypods

Chaenomya? cf. carinata Etheridge Jnr, 1892

T109. 3.7 km north-northwest of Cracow/Theodore road crossing of Delusion Creek. Between 670 and 700 m above base of formation.

Brachiopods

Cleiothyridina sp.

Corals

Thamnopora sp.
Cladochonus sp.

Crinoids

Calceolispongia kalewaensis Dickins, 1968 (same as in Barfield Formation near Baralaba)
Other plates

T110. 3.7 km north-northwest of Cracow/Theodore road crossing of Delusion Creek, about 200 m west of T109. Between 670 and 700 m above base of formation.

Pelecypods

Myonia carinata (Morris, 1845)
Streblopteria sp.

Brachiopods

Neospirifer sp. B
Licharewia sp. nov.*

Fenestellid and branching bryozoans

Single coral

Crinoids

Calceolispongia kalewaensis Dickins, 1968

Glendonites

*Previously referred to Pseudosyrinx sp. In a strict sense this species as shown is close to Licharewia as used by Slusareva (1960), although possibly Licharewia could be regarded as a subgenus of Pseudosyrinx. The species is quite distinct from that found in the Buffel Formation (Fauna II) which is closer to Pseudosyrinx s.s.

T111. 3.4 km north-northwest of Cracow/Theodore road crossing of Delusion Creek, about 0.4 km west of T110. About 750 m above base of formation.

Pelecypods

Chaenomya? carinata Etheridge Jnr, 1892. (left valve may lack a carina)
Atomodesma sp. ind.
Streblopteria? sp. ind.

Gastropods

Platyteichum coniforme (Etheridge Jnr, 1892) (has a consistently greater apical angle than found in P. costatum Campbell, 1953 from the Ingelara Formation)

Brachiopods

Cancrinella cf. magniplica Campbell, 1953
Terrakea sp. (non-geniculate, as in basal Fauna IV)
Strophalosia cf. typica (Booker, 1929) (same as in basal Fauna IV in northern part of basin - probably different species to S. typica)
Lissochonetes sp. (regarded by Wass as distinctive from L. semicircularis Campbell, 1953 from Ingelara Formation)
Neospirifer sp. ind.
Licharewia sp. nov. (surface lacks pustules but has fine lamellae)
Ingelarella mantuanensis Campbell, 1960 (some approach I. ingelarensis in shape)
Ingelarella cf. isbelli Campbell, 1961
Cleiothyridina sp.
Plekonella sp.
Attenuatella sp.

Serpulid worms

T117. 1.6 km south-southwest of Cracow/Theodore road crossing of Oxtrack Creek. Near top, about 910 m above base of formation.

Pelecypods

Cyrtorostra? sp. ind.

Brachiopods

Ingelarella mantuanensis Campbell, 1960

Single corals

T129. 2.9 km northwest of Gyranda turn-off from Cracow/Theodore road. About 730 m above base of formation.

Pelecypods

Chaenomya sp. (seems closest to specimens from Mantuan Productus Bed)
Streblopteria sp.

Gastropods

Platyteichum coniforme (Etheridge Jnr, 1892)

Brachipods

Terrakea sp. (as at 111, differs from specimens in Catherine Sandstone)
Ingelarella mantuanensis Campbell, 1960 (some approach I. ingelarensis in depth of sulcus)

Corals

Thamnopora sp.

Glendonites

T130. Small creek 1.6 km north of Mount Steel.

Pelecypods

Glyptoleda glomerata Fletcher, 1945

Brachiopods

Cancrinella cf. magniplica Campbell, 1953
Terrakea solida (Etheridge & Dun, 1909)
Lissochonetes sp.
Ingelarella mantuanensis Campbell, 1960

Corals

Thamnopora sp.
Cladochonus sp.
Single corals

Smooth conulariid

Relationships

Further evidence for assigning the fauna of the Oxtrack, Barfield, and Flat Top Formations to Fauna IV is afforded by the occurrence of Myonia carinata, Platyteichum coniforme, and Licharewia sp. nov. in the Barfield Formation. These three species are found also in the overlying Flat Top Formation. Evidence suggesting that the coquinites of the upper part of the Barfield Formation and the lower part of the Flat Top Formation are equivalent to the interval in the northern part of the basin containing the Big Strophalosia Zone and the Streptorynchus pelicanensis Bed is considered on page 118 .

FLAT TOP FORMATION

T274. 3.7 km southwest of The Braes homestead.

Pelecypods

Myonia carinata (Morris, 1845)
Chaenomya? cf. carinata Etheridge Jnr, 1892 (in two shells, left carinate and right valves rounded)
Atomodesma sp.

Gastropods

Warthia sp.
Platyteichum cf. coniforme (Etheridge Jnr, 1892)

The Flat Top Formation is poorly fossiliferous in the Mundubbera areas, so that identifications from three localities in the Monto Sheet area are added to allow a more complete understanding of the fauna.

D13. Quarry on Lonesome Creek (Theodore/Banana road, 12.2 km from Theodore Post Office and 5 km from junction with Camboon/Banana road, ref. 304908, Monto 4-mile Sheet)*.

Pelecypods

Nuculopsis (Nuculopsis) sp.
Parallelodon sp. nov. B
Myonia carinata (Morris, 1845)
Pyramus sp. (very narrow, elongated, produced further in front than form from Ingelara Formation, close to species from Ba321, Baralaba area, and CL12/2 and CL14, Clermont area)
Chaenomya? cf. carinata Etheridge Jnr, 1892
Chaenomya sp. (squashed, but seems similar to Fauna IV species)
Volsellina? mytiliformis (Etheridge Jnr, 1892)
Atomodesma bisulcatum Dickins, 1961
Aviculopecten sp.
Pseudomonotis? sp.
Cyrtorostra? sp.
Plagiostoma? sp. nov.
Stutchburia costata (Morris, 1845)
Schizodus sp. nov. C. (Fauna IV type)
Conocardium sp.

Gastropods

Stachella sp.
Mourlonia (Mourlonopsis) cf. strzeleckiana (Morris, 1845)

Brachiopods

Cancrinella cf. magniplica Campbell, 1953
Terrakea solida (Etheridge & Dun, 1909)**
Lissochonetes sp.
Strophalosia sp. ind.
Licharewia sp. nov.
Ingelarella mantuanensis Campbell, 1960 (includes some specimens of I. pelicanensis-type)
Notospirifer minutus Campbell, 1960
'Martinia' sp.
Streptorynchus pelicanensis Fletcher, 1952

* Whether this locality is at the top of the Barfield Formation or at the base of the Flat Top Formation is uncertain. J.F. Dear is now of the opinion (letter of 20th April 1964) that it is in the uppermost part of the Barfield Formation and that the base of the Flat Top Formation is approximately 100 m west of the quarry. For convenience, in the present Report, it is regarded as being in the Barfield/Flat Top transition beds.

** Considerable latitude has been used is assigning specimens to this species. The specimens exhibit distinct umbonal thickening, are not particularly geniculate, and have a similar spine pattern. They vary considerably in size, overall dimensions, and in the development of the muscle platform. Discrete groupings within that used are difficult to separate out. Most, if not all, of the variations can be matched in specimens referred to T. solida from Fauna IV localities elsewhere in the basin.

Fenestellid bryozoans

D43. Barfield/Banana road, quarry approximately 3 km north-northeast of Mount Flat Top (ref. 316945, Monto 4-mile Sheet).

Pelecypods

Myonia carinata (Morris, 1845)
Chaenomya? cf. carinata Etheridge Jnr, 1892

Gastropods

Platyteichum sp. ind.

Brachiopods

Productidae gen., sp. nov.* (known only from Flat Top Formation)
Strophalosia clarkei var. minima Maxwell, 1954
Strophalosia ovalis Maxwell, 1954.
Lissochonetes sp.
Licharewia sp. nov.
Ingelarella mantuanensis Campbell, 1960 (includes specimens which in shape are similar to I. pelicanensis)
'Martinia' sp.
Plekonella sp.

D52. North side Banana/Biloela road, approximately 6.5 km northeast of Banana (ref. 310956, Monto 4-mile Sheet).

Pelecypods

Aviculopecten sp.

Gastropods

Walnichollsia? sp. (like Walnichollsia, but carinate at all growth stages)

Brachiopods

Ingelarella mantuanensis Campbell, 1960
'Martinia' sp.

This represents a small selective collection made from a much larger fauna.

Relationships

The fauna from the Flat Top Formation and that from the quarry on the Lonesome Creek road is especially closely related to the faunas from the Streptorhynchus pelicanensis Bed of the Bowen area, the pelecypod bed of the Clermont area, and the Mantuan Productus Bed of the Springsure area. This is indicated by the occurrence of Atomodesma bisulcatum, Notospirifer minutus, and Streptorhynchus pelicanensis (perhaps somewhat remarkably, the Streptorphychus pelicanensis Bed and the pelecypod bed are lithologically similar to the Flat Top Formation). The fauna is also similar to that of the Big Strophalosia Zone of the Bowen area and the clarkei-bed of the Clermont area, which appear to contain N. minutus but so far lack Atomodesma bisulcatum and Streptorhynchus pelicanensis. For reasons already set out, the fauna is a Fauna IV. This is confirmed by the occurrence of Schizodus sp. nov. C, Atomodesma bisulcatum and N. minutus.

* Now named Filiconcha hillae Dear, 1969.

Productidae gen., sp. nov. and '*Martinia*' sp.* have not been identified from other parts of the basin. They make up only a small proportion of the species present, however, and seem to reflect local conditions rather than have any special age significance. The upper part of the Barfield Formation and the lower part of the Flat Top Formation, therefore, appear to represent the stratigraphical interval in the northern part of the basin extending from the Big *Strophalosia* Zone to the *Streptorhynchus pelicanensis* Bed, and the upper part of the Peawaddy Formation of the Springsure Sheet area. The alternative explanation that the Oxtrack Formation is to be equated with the Mantuan *Productus* Bed and its equivalent and that the Flat Top Formation is, therefore, younger, is not as acceptable on faunal grounds. It is also less acceptable on regional stratigraphical evidence which includes some indication from drilling that the Flat Top Formation may be, in part at least, the lateral equivalent of the Black Alley Shale (= the lower part of the Bandanna Formation).

* In these collections '*Martinia*' sp. was not found below the upper part of the Barfield Formation. Since the examination of these specimens was completed, however, R.E. Wass has informed me that he has found '*Martinia*' sp. in the Oxtrack Formation, northwest of Cracow homestead.

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APPENDIX 3

PLANT FOSSILS FROM THE TAROOM AND MUNDUBBERA SHEET AREAS

by

Mary E. White

SUMMARY

Plant fossils were collected at eighteen localities in the Taroom region of Queensland in 1963. The Gyranda Formation contains a regular component of Lower Permian flora found elsewhere in Australia, but may be Upper Permian in age; the Baralaba Coal Measures are Upper Permian. Three localities in the Moolayember Formation contain a flora of Triassic or Trias/Lower Jurassic age. The flora at the eight localities in the Evergreen Formation indicates a Jurassic age.

INTRODUCTION

Plant fossils were collected from eighteen localities in the Taroom and the Mundubbera Sheet area in 1963. The fossil horizons are in the Gyranda Formation, the Baralaba Coal Measures, the Rewan Formation, the Moolayember Formation, and the Evergreen Formation.

GYRANDA FORMATION AND BARALABA COAL MEASURES

Locality T54. 1.5 km southeast of Gyranda Pumping Station. Gyranda Formation. Specimens F22343*, F22344.

Glossopteris browniana Brong.
Glossopteris indica Sch.
Glossopteris stricta Bunb.
Glossopteris tortuosa Zeiller
Glossopteris ampla Dana
Glossopteris scale leaves
Gangamopteris cyclopteroides Feist.
Sphenopteris polymorpha Feist.

Age: Permian. Gangamopteris cyclopteroides Feist. is a regular component of Lower Permian floras in Australia; it is absent in typical Upper Permian assemblages. In view of the evidence that the marine faunas in the Oxtrack, Barfield, and Flat Top Formations underlying the Gyranda Formation are regarded as Upper Permian (see Appendix 2, p. 108) it must be assumed that Gangamopteris cyclopteroides passes into Upper Permian occasionally.

Locality T38. 6.4 km south of Back Creek and 7.25 km west-southwest of Cracow homestead. Gyranda Formation. Specimens F22357.

Glossopteris indica Sch.
Glossopteris ampla Dana
Glossopteris stricta Bunb.
Vertebraria indica Royle
Sphenopteris polymorpha Feist.

Age: Permian. There are no forms present which are diagnostic of Upper or Lower Permian.

Locality T157. 1.5 km northeast of Kia Ora homestead. Probably top of Gyranda Formation. Specimens F22351.

*BMR registered fossil number.

Glossopteris damudica Feist.
Glossopteris ampla Dana
Glossopteris conspicua Feist.
Glossopteris indica Sch.
Glossopteris angustifolia Brong.
Glossopteris scale leaves
Gangamopteroid small leaves and fragments of the type associated with Lidgettonia australis (White, 1960)
Vertebraria indica Royle
Sphenopteris polymorpha Feist.

Age: Upper Permian. Glossopteris conspicua does not occur in the Lower Permian.

Locality T92. 1.5 km southwest of Gyranda Pumping Station. Baralaba Coal Measures, above Gyranda Formation. Specimens F22345, F22345a,b, F22346.

The following Glossopteris assemblage is present:

Glossopteris indica Sch.
Glossopteris damudica Feist. F22345b, CPC11127*, Pl. A, fig. 2(1)
Glossopteris conspicua Feist. F22345a, CPC11128, Pl. A, fig. 1(1)
Glossopteris parallela Feist. F22345a, CPC11129, Pl. A, fig. 1(2)
Glossopteris angustifolia Brong. F22345a, CPC11130, Pl. A, fig. 1(3)
Glossopteris communis Feist. F22345b, CPC11131, Pl. A, fig. 2(2)
Vertebraria indica Royle

Age: Upper Permian.

Locality T93. 1.5 km southwest of Gyranda Pumping Station. Baralaba Coal Measures, above Gyranda Formation. Specimens F22347, F22348, F22349, F22350.

These specimens are beautifully preserved and contain fossils of considerable interest. In specimens F22347-49, stems and leaf whorls of all sizes of Phyllotheca etheridgei Arber occur in great profusion. They are illustrated in Plate A, figures 3 and 4 and Plate B. It will be observed that the leaf whorls in young stems are ensheathing, with long free segments, and that the older sheaths have a disc form with reduction in the relative lengths of united and free segments. Mature whorls are tooth-edged discs.

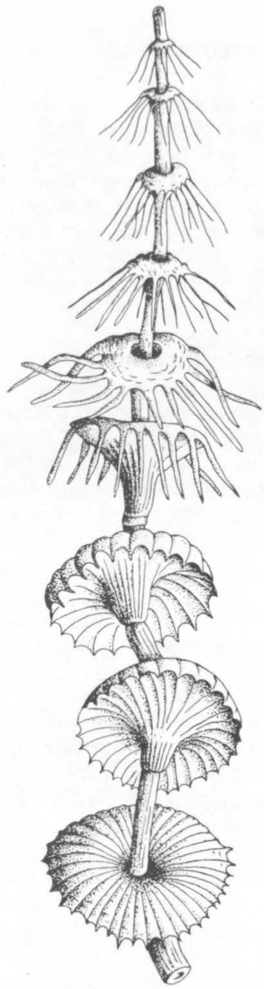
Text-figure A shows a reconstruction of a shoot of Phyllotheca etheridgei (after Saksena, 1954) which illustrates the arrangement of sheaths on a stem. In a recent paper by Rigby (1962) mature sheaths in which the free segments are very much reduced are described as Ranigangia indica (Srivastava) Rigby nov. comb. These specimens from Baralaba, Queensland, are probably referable to Phyllotheca etheridgei. The type material of Phyllotheca etheridgei was collected from the Newcastle Coal Measures of New South Wales.

The specimens in which P. etheridgei occur in the present collection in such profusion have no associated plant species. The occurrence of a pure zone of equisetalean fossils is characteristic and indicates swamp conditions in which the plants grew as 'reeds'.

Specimens F22350 from the same locality but from a different fossil layer contain the following species (without any examples of Phyllotheca etheridgei):

Glossopteris browniana Brong.
Glossopteris stricta Bunb.
Glossopteris communis Feist. CPC11138, Pl. C, fig. 1
Sphenopteris polymorpha Feist.

*Commonwealth palaeontological collection type number.



Text-figure A. Reconstruction of a branch of Phyllotheca etheridgei Arber (after Saksena, 1954).

Age: Permian. On the presence of Phyllotheca etheridgei an Upper Permian age is suggested.

Locality T33. 4 km southwest of Gyranda Pumping Station. Baralaba Coal Measures, above the Gyranda Formation (higher in the Coal Measures than 157, 92, and 93). Specimens F22342.

Indeterminate stem casts and impressions and finely macerated plant material.

Age: Indeterminate.

REWAN FORMATION

Locality T71. 5 km north-northeast of Dawson River/Downfall Creek junction, 0.8 km south of Dawson River. Rewan Formation. Specimens F22381.

These specimens are very poor and contain indeterminate impressions of stem fragments. One small frond of fern is present. It is referred to cf. Dicroidium odontopteroides (Morr.) Gothan. A fragment of venation of Cladophlebis type is also present.

Age: Triassic(?) or Lower Jurassic.

MOOLAYEMBER FORMATION

Locality T173. 5.5 to 6.5 km south of Glenbar homestead. Moolayember Formation. Specimens F22382.

Preservation of these specimens is poor. Some pinnule fragments of Dicroidium odontopteroides (Morr.) Gothan are present. The range of this is Triassic to Lower Jurassic.

Age: Triassic or Lower Jurassic.

Locality T549. 4 km northeast of Mopola homestead. Moolayember Formation. Specimens F22384, F22385, F22386.

Preservation of these specimens is exceptionally good. Plate E, figure 2 illustrates specimen F22384 (CPC11144) of Dicroidium odontopteroides (Morr.) Gothan. Plate E, figure 4 of specimen F22385 (CPC11145) shows Thinnfeldia acuta Walkom, which was described from the Ipswich and Walloon Series in Queensland (Walkom, 1915).

The rest of the specimens (F22386) contain further examples of D. odontopteroides (including D. lancifolia) associated with equisetalean stems.

Age: Triassic or Lower Jurassic.

AGE OF MOOLAYEMBER FORMATION

On plant evidence the age of the Moolayember Formation is Triassic or Lower Jurassic.

EVERGREEN FORMATION

Locality T641. 0.8 km west of Red Range homestead in Cockatoo Creek. Specimens F22352.

A very poorly preserved conifer twig similar to those determined as Pagiopnyllum peregrinum at locality T735 is present.

Age: Mesozoic.

Locality T642. 1.5 km west of Red Range homestead in Cockatoo Creek. Specimens F22353.

These specimens are poorly preserved. Small indeterminate stems are present with macerated plant material, including fragments of pinnule of Cladophlebis australis (Morr.) and Dicrodium cf. D. odontopteroides.

The range of Cladophlebis australis is Upper Triassic to Lower Cretaceous. Dicroidium odontopteroides ranges from Triassic to Lower Jurassic. The characteristic Dicroidium flora in which the genus attains its greatest profusion is Middle Triassic. Some species occur in Jurassic, and a few persist to Lower Cretaceous (not odontopteroides).

Age: Triassic or Jurassic.

Locality T653. From road crossing of Sandy Creek, 8 km east-southeast of Cockatoo homestead. Specimens F22354.

These specimens contain very finely macerated plant remains, which are for the most part indeterminate. Repeated splitting of the specimens and minute examination of the plant fragments have made the following determinations possible:

Cladophlebis australis (Morr.). CPC11139, Pl. C, fig. 2
Coniopteris delicatula (Shirley)
Otozamites obtusus L. & H.
Nilssonia minima Gothan
Minute frond with tripinnate projections

Cladophlebis australis ranges from Upper Triassic to Lower Cretaceous. Coniopteris delicatula occurs in the Ipswich and Walloon, Queensland. Otozamites occurs in Jurassic and Lower Cretaceous, not in Triassic. Nilssonia minima is a Jurassic form. The specimens in this collection referred to this species are minute fragments and some doubt must exist as to their specific identification. They were obviously fronds of substantial leathery texture. Nilssonia, Pterophyllum, and associated genera have an Upper Triassic to Lower Cretaceous range, with particular abundance in the Jurassic.

Some small shells were found in the specimens.

Age: Jurassic or Lower Cretaceous. The weight of evidence seems to favour a Jurassic age.

Locality T666. On the road between Red Range and Murungla homesteads, 400 m south of Cockatoo Creek and 10 km east-northeast of Red Range homestead. Specimens F22355.

This coarse-grained specimen contains one fern frond approximately 10 cm long with pinnules, almost opposite in arrangement, which are apparently decurrent. Each pinnule has a prominent median vein and the secondary venation appears to be very fine and more or less parallel. Pinnules at the base of the frond are about 1 cm long, those at the top of the frond about 0.5 cm long. As the secondary venation is not distinct and preservation is very poor, no determination can be made. Ferns of the same general form occur throughout Mesozoic time.

Age: Indeterminate.

Locality T670. On the road immediately south of and at the foot of Marr Hill, 1.5 km east-northeast of Red Range homestead. Specimens F22356.

Indeterminate stem casts and impressions.

Age: Indeterminate.

Locality T693. 0.8 km southeast of Bungabin homestead on Bungabin Creek. Specimens F22358.

Indeterminate stem casts

Age: Indeterminate.

Locality T653b. From the road crossing of Sandy Creek, 8 km east-southeast of Cockatoo homestead. Specimens F22387.

The plant remains in these specimens are finely macerated. One small portion of frond of Cladophlebis australis (Morr.) and a few pinnules of Coniopteris delicatula (Shirley) are the only determinate fossils.

Age: Triassic or Jurassic.

Locality T735. At Dawson Vale near Homestead. Specimens F22359-64.

Conifer foliage of two types is present in great quantities in these specimens. A nodal diaphragm referable to Equisitites sp. is the only fossil not of conifer origin.

Twigs of Pagiophyllum peregrinum (L. and H.) with falcate overlapping leaves are illustrated in Plate D, figures 1 and 2 (specimen F22359, CPC 11140). This conifer has a Jurassic and Lower Cretaceous distribution. (Jurassic in Europe, Rajmahal and Jabalpur in India, Burrum Series in Queensland, Talbragar Fish Beds in NSW etc.). In specimen F22361 Pagiophyllum is associated with conifer foliage of a second type, probably referable to Retinosporites indica Feist.

In specimen F22362 (CPC11141) seen in Plate D, figure 3, needle leaves of a conifer occur in great profusion. They have no midrib. Two examples of young shoots with attached leaves are present in the collection, showing the attachment of leaves. The needles are decurrent and overlap on the stem in the same manner as seen in Retinosporites indica Feist. There are also two older stems which are poorly preserved but which show needles attached in close formation. Retinosporites indica occurs in the Sripematur Stage of the Upper Gondwanas in India.

Specimen F22363 (CPC11142), illustrated in Plate E, figure 1, shows a conifer branch bearing male cones or short shoots.

Specimen F22364 (CPC11143), shown in Plate E, figure 3, contains an obscure fructification. Preservation is poor and no reliable guess can be made as to the nature of this fossil.

Age: Jurassic or Lower Cretaceous.

AGE OF THE EVERGREEN FORMATION

Plant evidence proves that the Evergreen Formation is of Jurassic age.

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PLATE A

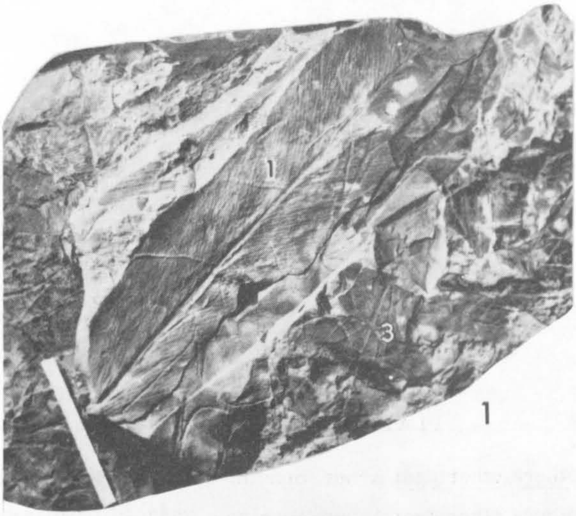
Fig.1. 1. Glossopteris conspicua Feist. (CPC11128); 2. Glossopteris parallela Feist. (CPC11129); 3. Glossopteris angustifolia Brong. (CPC11130). Specimen F22345a, x ½.

Fig.2. 1. Glossopteris damudica Feist. (CPC11127); 2. Glossopteris communis Feist. (CPC11131). Specimen F22345b, x 2/3.

Fig.3. 1. Phyllotheca etheridgei Arber. Specimen F22347 (CPC11132), x 1 1/3.

Fig.4. 2. Phyllotheca etheridgei Arber. Specimen F22348 (CPC11133), x 1 3/4.

PLATE A



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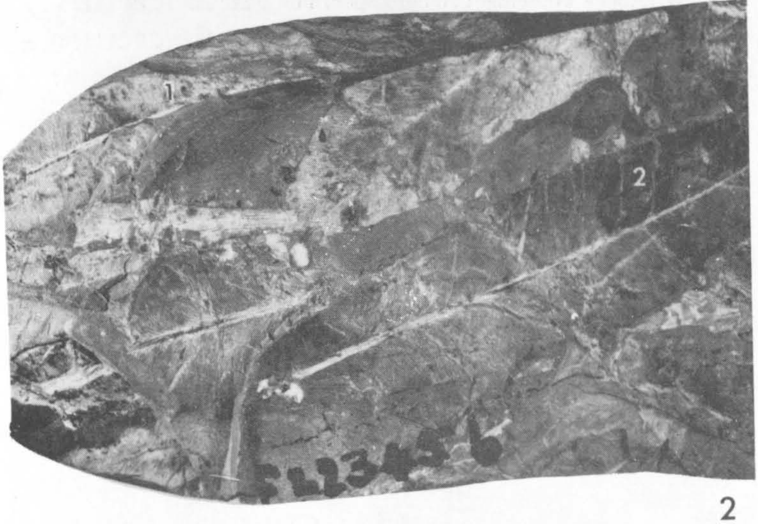

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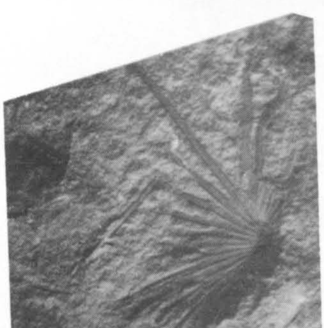

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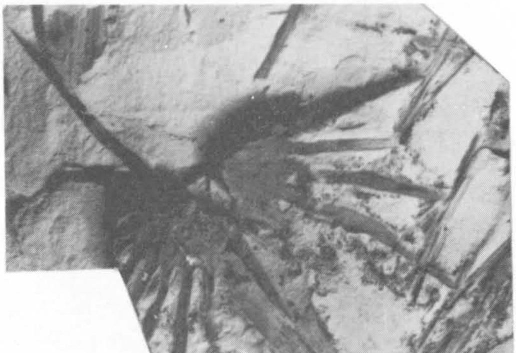


4

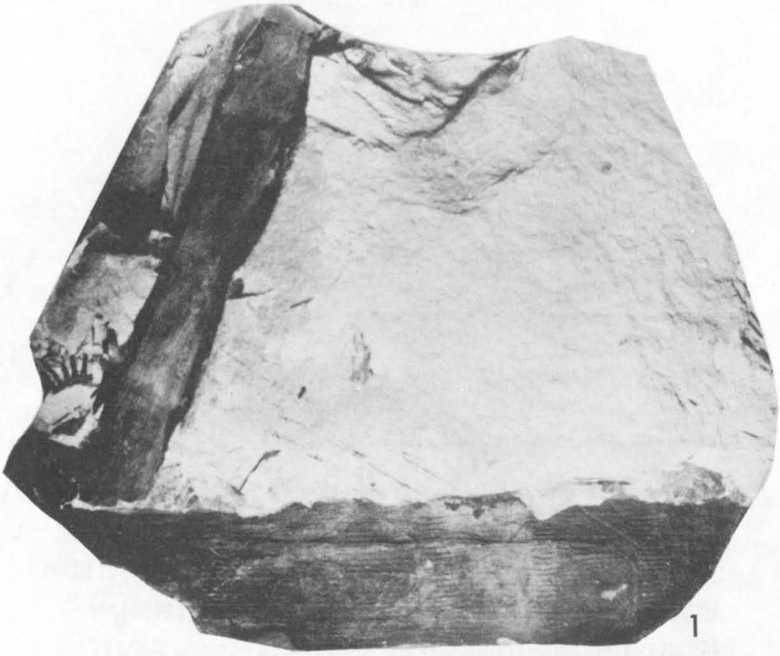
PLATE B

Fig.1. Phyllotheca etheridgei Arber. Specimen F22349 (CPC11134), x 1.

Fig.2. Phyllotheca etheridgei Arber. Specimen F22348a (CPC11135), x 2.

Fig.3. Phyllotheca etheridgei Arber. Specimen F22348b (CPC11136), x 3.

PLATE B



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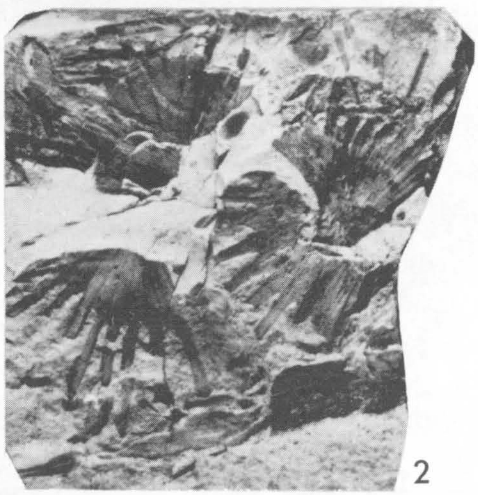

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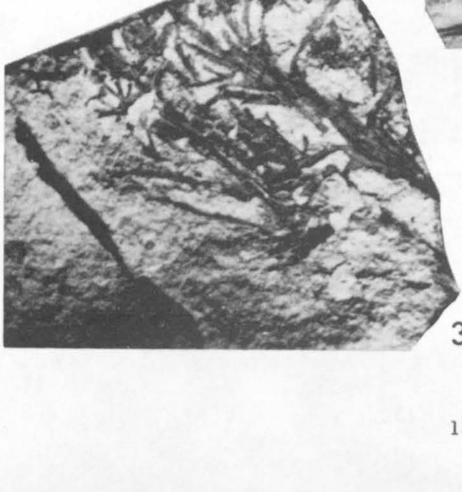


3

PLATE C

Fig.1. Glossopteris communis Feist. Specimen F22350a (CPC11138), x 1½.

Fig.2. Cladophlebis australis (Morr.). Specimen F22354 (CPC11139), x 2½.

Fig.3. Coniopteris delicatula (Shirley). Specimen F22354 (CPC11137), x 5.

Fig.4. Nilssonia minima Gothan. Specimen F22354 (CPC11146), x 4.

Fig.5. Minute frond with tripinnate projections. Specimen F22354 (CPC11458), x 5.

PLATE C

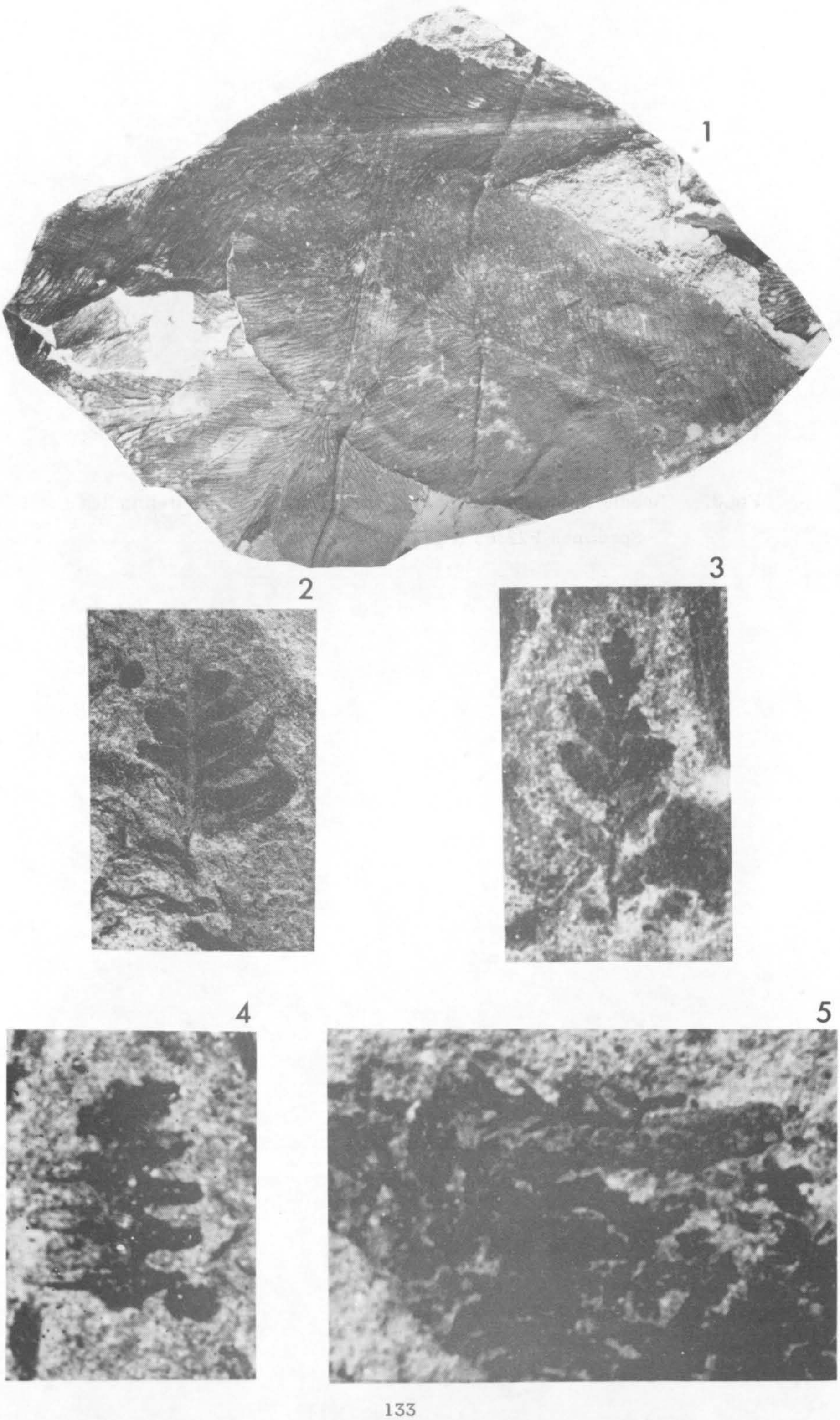
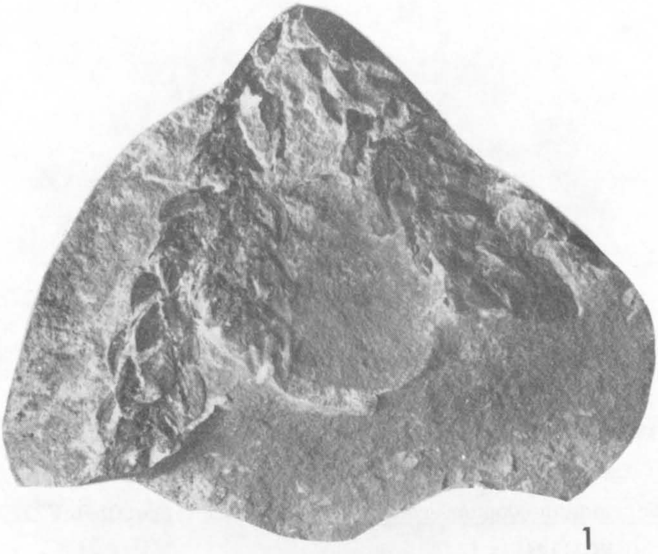


PLATE D

Figs 1 and 2. Pagiophyllum perigrinum (L and H). Specimen F22359 (CPC11140). Fig. 1 x 2, Fig. 2 x 1.

Fig.3. Needle leaves of a conifer, presumably Retinsporites indica Feist. Specimen F22363 (CPC11141), x 2/3.

PLATE D



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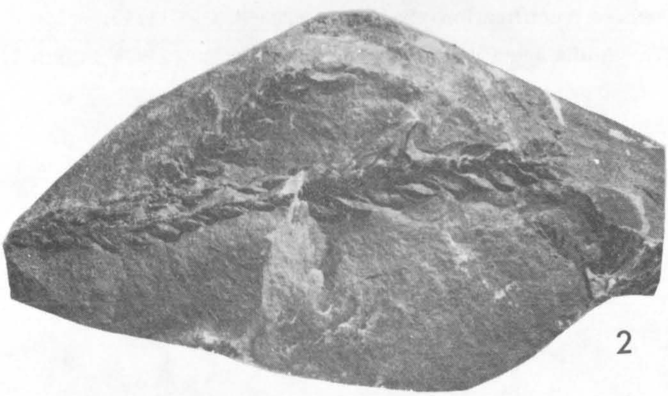


2

3

PLATE E

Fig.1. Male cones or short shoots of a conifer. Specimen F22363 (CPC11142), x 2/3.

Fig.2. Dicroidium odontopteroides (Morr.) Gothan. Specimen F22384 (CPC11144), x 1.

Fig.3. Obscure fructification. Specimen F22364 (CPC11143), x 1.

Fig.4. Thinnfeldia acuta Walkom. Specimen F22385 (CPC11145), x 1.

PLATE E

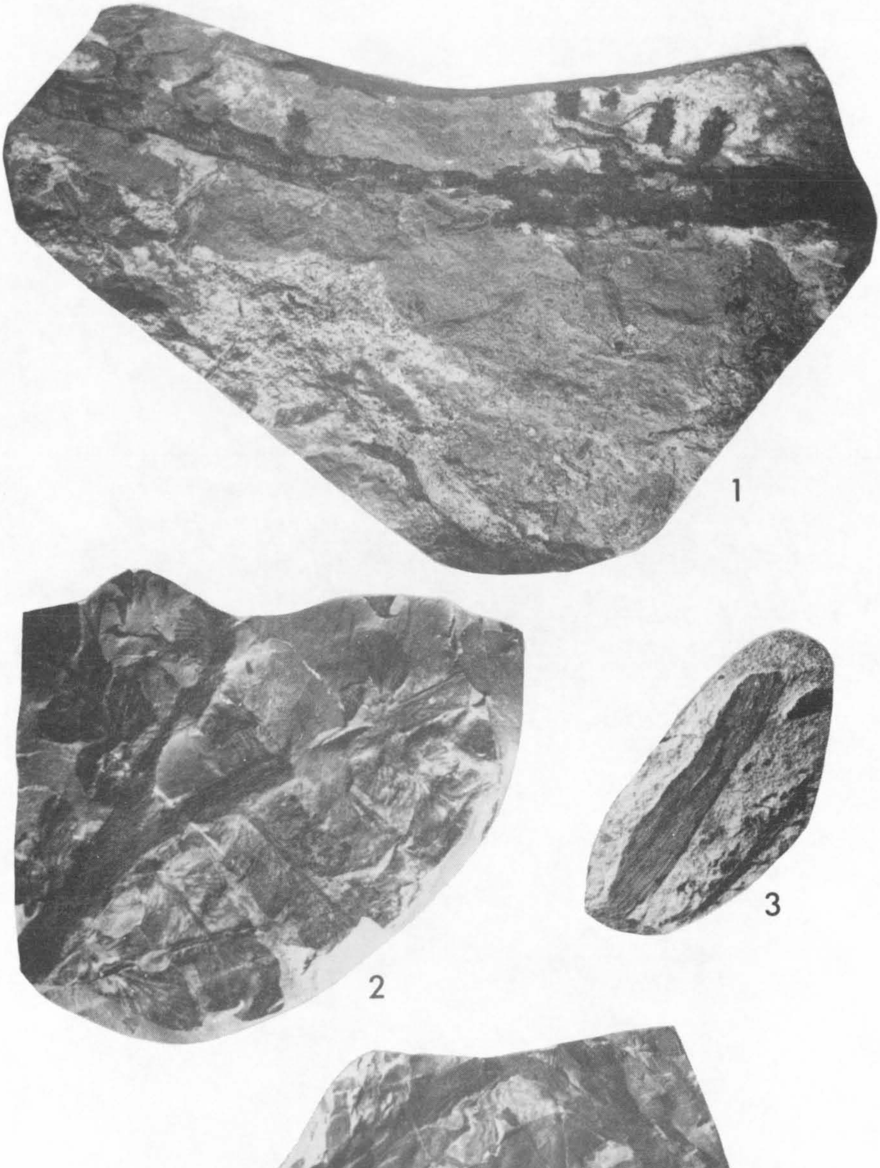


PLATE I. CORRELATION OF JURASSIC SEQUENCE IN OIL EXPLORATION WELLS AND OUTCROP

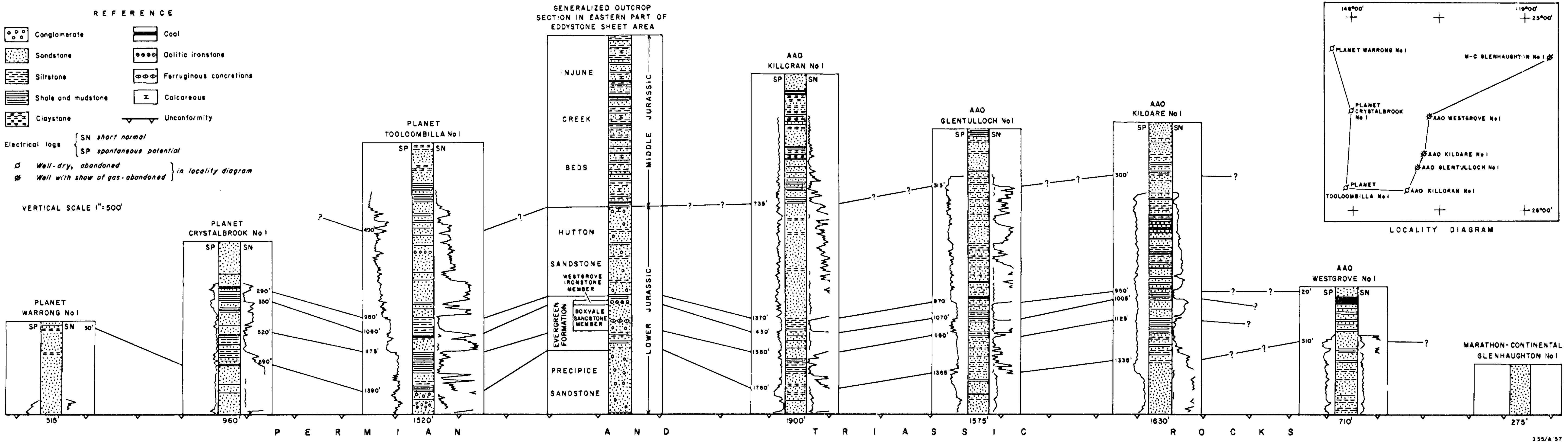
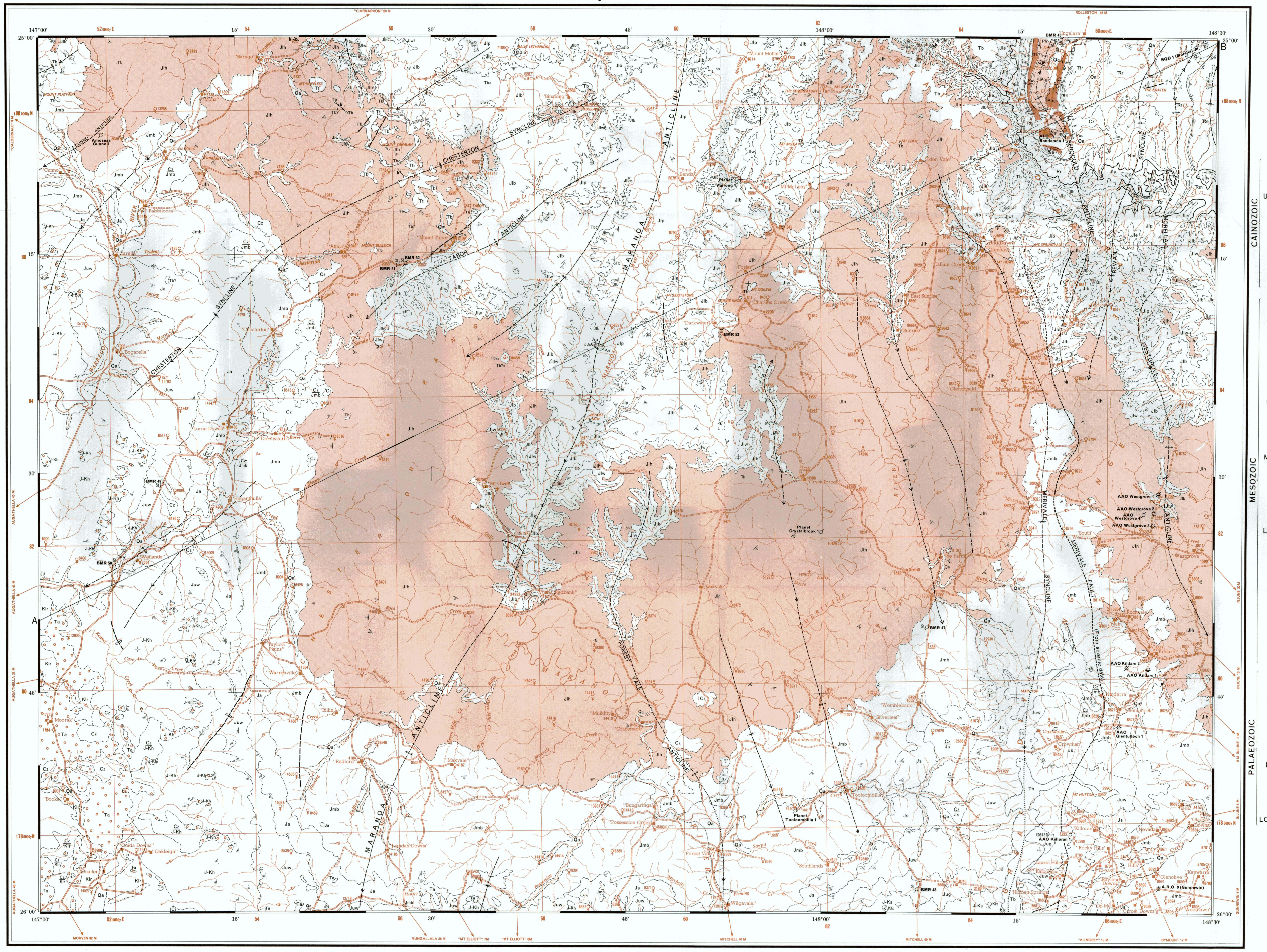



PLATE 2
CORRELATION OF SHALLOW STRATIGRAPHIC HOLES
AND MEASURED SECTIONS IN LOWER JURASSIC FORMATIONS
E 8---------- Eddystone Sheet, section no. 8
TA 23------- Taroom Sheet, section no. 23
ED BMR 51--- Stratigraphic drill hole, no. 51, Eddystone Sheet
TA BMR 46-- Stratigraphic drill hole, no. 46, Taroom Sheet
MU BMR 29-- Stratigraphic drill hole, no. 29, Mundubbera Sheet
T 766 --- Shelly fossil collection number
T 641 --- Plant fossil collection number
T 643 --- Sample for palynological examination
Ab------- Section measured using Abney Level
Ba------- Section measured using Aneroid Barometer
LOCALITY MAP
Showing locations and lines of sections, and area of outcrop of Lower Jurassic formations (unshaded)
PRE L. JURASSIC
POST LOWER JURASSIC
EDDYSTONE
TAROOM
MUNDUBBERA
20 MLS
Note: Exact locations of sections shown on 1:250,000 Sheets
VERTICAL SCALE (IN FEET)
INJUNE CREEK BEDS
HUTTON SANDSTONE
EVERGREEN FORMATION
PRECIPICE SANDSTONE
MOOLAYEMBER FORMATION
WESTGROVE IRONSTONE MEMBER
BOXVALE SANDSTONE MEMBER
OOLITE MEMBER
TYPE SECTION WESTGROVE IRONSTONE MEMBER
TA 25 TYPE SECTION HUTTON SANDSTONE
TA 24 TYPE SECTION PRECIPICE SANDSTONE, EVERGREEN FORMATION (mts to top of Boxvale Sandstone Member)
COMPOSITE SECTION FROM FIELD OBSERVATIONS MUNDUBBERA SHEET
penetrated in Planet Warrong No 1 Well
REFERENCE
Sandstone
Grain size mm
Very fine 0·06-0·12
Fine 0·12-0·25
Medium 0·25-1·00
Coarse 1·00-2·00
quartzose sandstone > 90% clasts of quartz
sublabile (feldspathic, lithic) 75-90% clasts of quartz
labile (feldspathic, lithic) < 75% clasts of quartz
Conglomerate
Granule 2·0-4·0
Pebble 4·0-64·0
Mudstone
Claystone
Siltstone
Coal
Calcareous lens / bed
Unconformity
Cored interval
Lithological gradation
Resistant bed
Concealed section
Resistant bed
Bedding structure
Very thick > 40 inches
Thick 12-40 inches
Medium 4-12 inches
Thin 0·4-4 inches
Laminate < 0·4 inches
Cross-bedded
Cross-laminated
Festoon bedded
Ripple marks - current
Trails
Other symbols
Ferruginous concretion
Calcareous concretion
Oolitic or pelletal ironstone
Shelly fossil
Plant fossil
Fossil wood
Palynological sample
Abbreviations
arg argillaceous
as abv as above
as blw as below
bl blue
bldrs boulders
blk black
brn brown
c coarse
c̄ with
calc calcareous
carb carboniferous
cgl conglomerate
cham chamositic
choc chocolate
clayst claystone
cln clean
cly clayey
crm cream
evn gr even grained
f fine
fe ferruginous
feld feldspathic
felds feldspar
fe-st ironstone
fe stnd iron stained
flgy flaggy
frag, s fragment, s
gn green
gr grained
gran granules
grns grains
gy grey
hd hard
HM heavy minerals
k khaki
lab labile
lt light
m medium
mi micaceous
mic mica
mod moderately
mudst mudstone
o/c outcrop
occ occasional
ool oolitic
p poor, poorly
pk pink
purp purple
qose quartzose
qtz or q quartz
q ss quartz sandsone
qtzite quartzite
r f rock fragments
sdy sandy
sft soft
siltst siltstone
slty silty
srtd sorted
ss sandstone
sublab sublabile
v very
w well
wh white
yel yellow
G55/A7/9

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

EDDYSTONE
QUEENSLAND

SHEET SG 55-7



Reference

- Geological boundary
- Important geological unconformity—base of Jlp
- Anticline
- Syncline
- Plunge of fold axis
- 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
- Dip <5°, Dip 5°–15°, Dip 15°–45°, Horizontal strata, Trend lines, Joint pattern — air-photo interpretation
- Macrofossil locality (ED675 —reference number)
- Vertebrate fossil locality
- Plant fossil locality
- Fossil wood locality
- Basalt dyke
- Prospect: little production-asbestos-amphibole
- Outcrop: C—coal, Ol—torbanite
- Dry oil exploration well—abandoned
- Gas well
- Abandoned well with show of oil and gas
- Abandoned well with show of oil
- Abandoned well with show of gas
- St BMR 50 Shallow stratigraphic drill hole
- Bore, Artesian bore, Subartesian bore, Abandoned bore — Where circle is broken, position is approximate
- 12686 —I.W.S. registered water bore number
- B10 —BMR water bore reference number
- Windpump
- Earth tank
- Earth dam
- Spring
- Road
- Vehicle track
- Landing ground
- "Attica" Homestead
- Building
- Yd Yard
- 1601′ Height in feet—instrument levelled; 2990′ Height in feet—barometric — datum: mean sea level

Reference

Era	Period	Unit	Symbol	Description
CAINOZOIC	QUATERNARY		Qa	Alluvium
	UNDIFFERENTIATED		Cz	Thick residual soil, "billy" and basalt boulder gravel
	TERTIARY			Laterite
			Ta	Pebbly clayey quartz-rich sandstone
			Tb	Basaltic flows, plugs; Basalt plugs
		Tabor Gabbro	Tt	Olivine gabbro sill and stocks
MESOZOIC	LOWER CRETACEOUS	Roma Formation	Klr	Siltstone, sublabile sandstone, shale
		Blythesdale Formation Claravale Sandstone Member	Klx	Cross-bedded quartzose sandstone, pebbly in part; minor siltstone, claystone
	JURASSIC-CRETACEOUS	Hooray Sandstone	J-Kh	Cross-bedded quartzose to sublabile sandstone, pebbly in part; minor siltstone and claystone
		Southlands Formation	J-Ks	Sublabile to labile sandstone, in part calcareous; mudstone, siltstone; quartz-rich sandstone in upper part
	UPPER JURASSIC	Gubberamunda Sandstone	Jug	Cross-bedded quartzose to sublabile sandstone; minor siltstone, mudstone
		Injune Creek Group: Westbourne Formation	Juw	Siltstone, mudstone, very fine-grained quartz-rich sandstone
	MIDDLE-UPPER JURASSIC	Injune Creek Group: Adori Sandstone	Ja	Cross-bedded feldspathic to sublabile sandstone, minor pebbly; minor siltstone, claystone
	MIDDLE JURASSIC	Injune Creek Group: Springbok Sandstone Member	Js	Cross-bedded labile sandstone, in part calcareous; some siltstone, carbonaceous mudstone and coal
		Injune Creek Group: Birkhead Formation	Jmb	Sublabile to labile sandstone, in part calcareous; carbonaceous siltstone and mudstone; some coal
	LOWER - MIDDLE JURASSIC	Hutton Sandstone	Jlh	Quartzose and sublabile sandstone; minor sublabile sandstone
	LOWER JURASSIC	Westgrove Ironstone Member	Jlw	Concretionary ironstone, oolitic in places; mudstone; includes at top some Jle (not separated on map)
		Boxvale Sandstone Member	Jlb	Quartzose sandstone, commonly micaceous; minor siltstone and coal
		Evergreen Formation	Jle	Labile and sublabile sandstone, carbonaceous shale, minor coal
		Precipice Sandstone	Jlp	Cross-bedded pebbly quartzose sandstone
	PRE-JURASSIC		pJs	Ferruginous and calcareous sediments
	TRIASSIC	Mimosa Group: Moolayember Formation	TRm	Siltstone, shale; labile to quartzose sandstone, calcareous in part
		Mimosa Group: Clematis Sandstone	TRe	Cross-bedded pebbly quartzose sandstone, red silty mudstone
		Rewan Formation	TRr	Red and green silty mudstone, green sublabile sandstone
		Brumby Sandstone Member	TRb	Pebbly labile and sublabile sandstone
PALAEOZOIC	UPPER PERMIAN	Blackwater Group	Puw	Green feldspatho-lithic sandstone, siltstone, shale, coal
		Back Creek Group: Black Alley Shale	Puc	Black shale, claystone, bentonitic claystone, bentonite, tuff
		Back Creek Group: Peawaddy Formation	Pup	Carbonaceous sandy shale, siltstone; feldspatho-lithic sandstone in upper beds
	LOWER PERMIAN	Back Creek Group: Ingelara Formation	Pli	Sandy siltstone with pebbles and granules, shelly calcareous concretions
		Back Creek Group: Aldebaran Sandstone	Pll	Quartzose sandstone, conglomerate; minor siltstone, coal (section only)
		Back Creek Group: Cattle Creek Formation	Plk	Conglomeratic sandy siltstone and silty sandstone, siltstone, coquinitic limestone (section only)
		Reids Dome Beds	Plj	Carbonaceous siltstone, shale, coal seams (section only)
	LOWER PALAEOZOIC		Pzr	Gabbro and ultrabasic plutonic rocks

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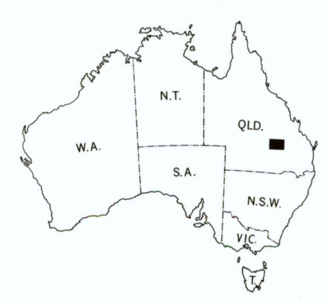


INDEX TO ADJOINING SHEETS
Showing Magnetic Declination

LONGREACH SF 55-13	JERICHO SF 55-14	EMERALD SF 55-15	DUARINGA SF 55-16	ROCKHAMPTON SF 56-13
BLACKALL SG 55-1	TAMBO SG 55-2	SPRINGSURE SG 55-3	BARALABA SG 55-4	MONTO SG 56-1
ADAVALE SG 55-5	AUGATHELLA SG 55-6	EDDYSTONE SG 55-7	TAROOM SG 55-8	MUNDUBBERA SG 56-5
QUILPIE SG 55-9	CHARLEVILLE SG 55-10	MITCHELL SG 55-11	ROMA SG 55-12	CHINCHILLA SG 56-9
TOOMPINE SG 55-13	WYANDRA SG 55-14	HOMEBOIN SG 55-15	SURAT SG 55-16	DALBY SG 56-13

ANNUAL CHANGE 3′E

Scale 1:250,000

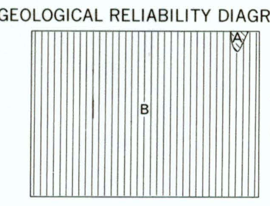
5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

GREY NUMBERED LINES INDICATE THE 20,000 YARD TRANSVERSE MERCATOR GRID, ZONE 7 (AUSTRALIA SERIES)

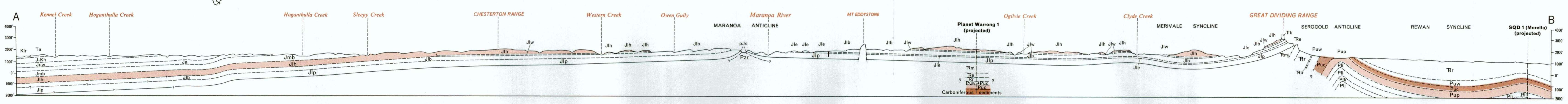
Section
Qa and Cz omitted
Scale: $\frac{V}{H} = 4$

GEOLOGICAL RELIABILITY DIAGRAM



A Detailed mapping
B Detailed reconnaissance

Geology and compilation, 1964, by R. G. Mollan, N. F. Exon (B.M.R.), and V. R. Forbes, (G.S.Q.); revised 1965 by N. F. Exon
Cartography by: Geological Branch, B.M.R.
Drawn by: Austral Cartographic Service, Canberra, A.C.T.



EDDYSTONE
SHEET SG 55-7

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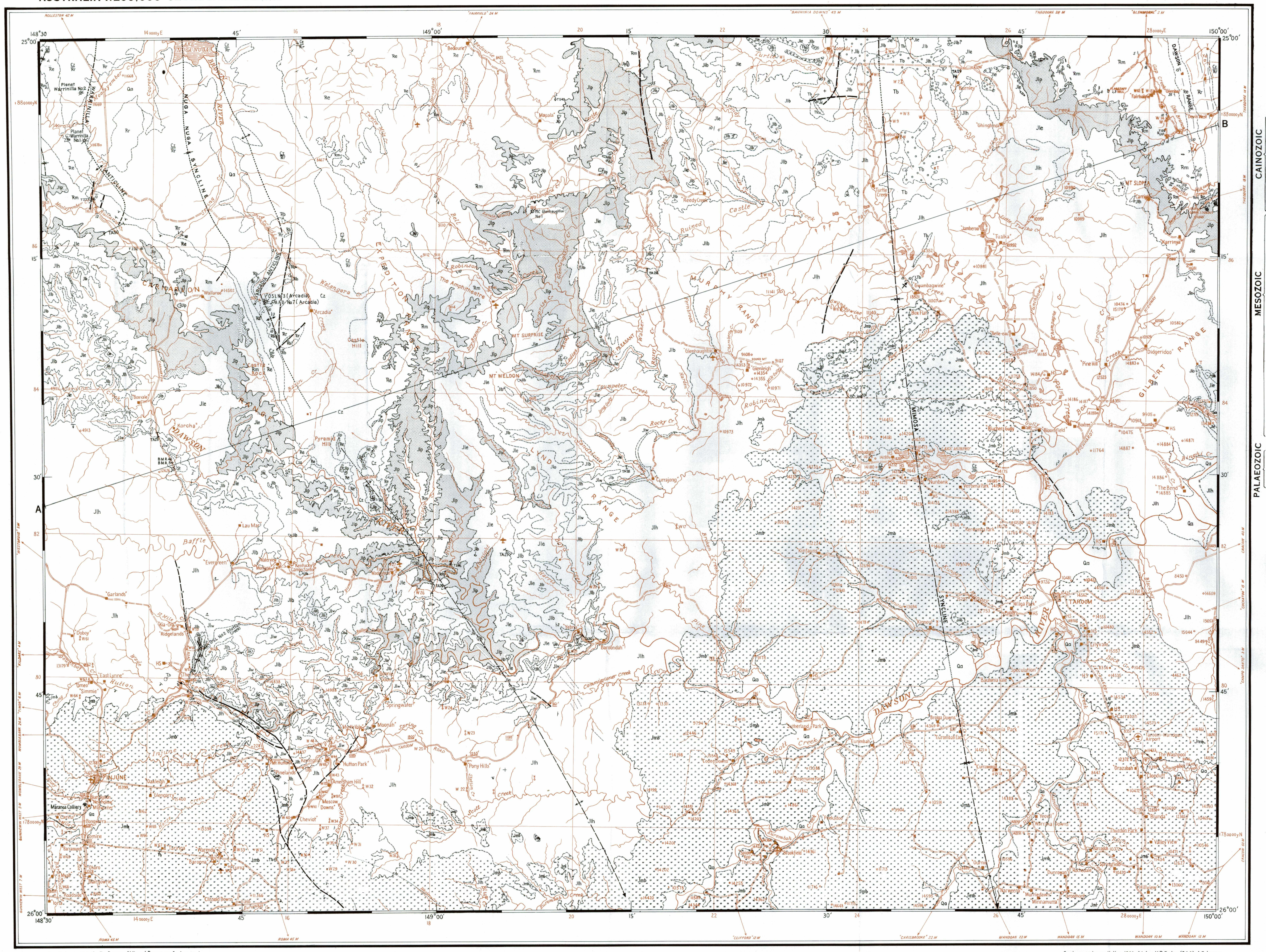
AUSTRALIA 1:250,000 GEOLOGICAL SERIES

TAROOM
QUEENSLAND

SHEET SG 55-8

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

PLATE 4



Reference

Era	Period	Unit	Symbol	Description
CAINOZOIC			Qa	Alluvium
			Cz	Soil, sand
				Laterite and lateritic soil
	TERTIARY		Tb	Basalt, minor quartzose sandstone
			T	Gabbro
MESOZOIC			J	Sediments (section only)
	MIDDLE JURASSIC	Birkhead Formation	Jmb	Calcareous lithic sandstone, calcareous siltstone, shale, carbonaceous shale, coal
	LOWER TO MIDDLE JURASSIC	Hutton Sandstone	Jlh	Argillaceous sublabile sandstone and quartzose sandstone
	LOWER JURASSIC	Westgrove Ironstone Member	Jlw	Chamositic ironstone, pelletal or oolitic in places, cropping out as concretionary or oolitic limonite
			Jlo	Chamositic ironstone, generally oolitic, cropping out as concretionary and oolitic limonite; minor mudstone and sandstone
		Boxvale Sandstone Member	Jlb	Quartzose sandstone, commonly micaceous; minor siltstone and coal
		Evergreen Formation	Jle	Labile and sublabile sandstone, mudstone; minor shale and coal
		Precipice Sandstone	Jlp	Quartzose sandstone, sublabile lithic sandstone, siltstone
	MIDDLE TO UPPER TRIASSIC	Moolayember Formation	Rm	Mudstone, lithic sandstone, sublabile lithic sandstone, conglomerate, carbonaceous shale, fine tuff
	MIDDLE TRIASSIC	Clematis Sandstone	Re	Quartzose and sublabile lithic sandstone, conglomerate, mudstone
	LOWER TRIASSIC	Rewan Formation	Rr	Brown mudstone, green lithic sandstone
		Brumby Sandstone Member	Rb	Conglomeratic coarse lithic sandstone
PALAEOZOIC	PERMIAN		P	Sediments (section only)
	LOWER PERMIAN		Pl	Sediments and volcanics (section only)

Geological boundary
Important regional unconformity - base Jlp
Syncline, showing plunge
Anticline, showing plunge
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

Strike and dip of strata
Dip < 5°
Horizontal strata
Dip < 15° (air-photo interpretation)
Trend lines (air-photo interpretation)
Joint pattern (air-photo interpretation)
b Basalt dyke
T 286 Microfossil locality
T 125 Plant fossil locality
N₁ Minor occurrence of nickel
Coal mine - not being worked
Abandoned oil well with show of gas
Dry hole (abandoned)
St Dry stratigraphic hole
TA 26 Measured section
Artesian water bore
Subartesian water bore
Abandoned water bore
W Well
4963 Queensland I.W.S. registered number
W 26 BMR Field reference number
Windpump
Lake
Spring
Earth dam
T Earth tank

Road
Vehicle track
Track
Railway with siding
Town
Settlement
"Blunda" / HS Homestead
Building
Airport
Landing ground
Yd Yard
·1288′ Height in feet, instrument levelled (datum: mean sea level)
·1190′ Height in feet, barometric (datum: mean sea level)

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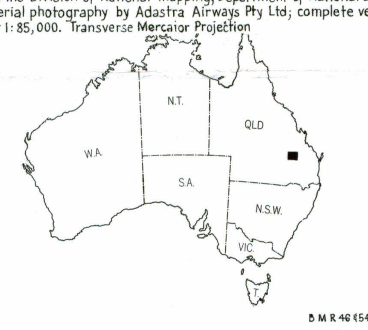
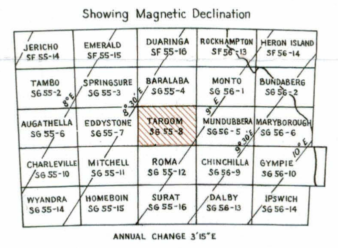


INDEX TO ADJOINING SHEETS
Showing Magnetic Declination



ANNUAL CHANGE 3′15″E

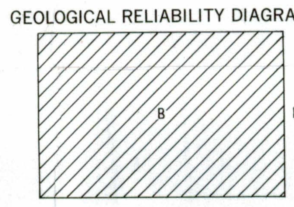
Scale 1 : 250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

GREY NUMBERED LINES INDICATE THE 20,000 YARD TRANSVERSE MERCATOR GRID, ZONE 8 (AUSTRALIA SERIES)

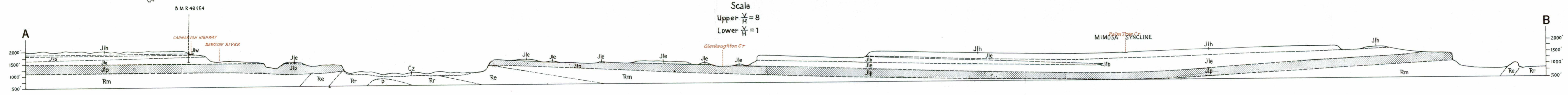
GEOLOGICAL RELIABILITY DIAGRAM

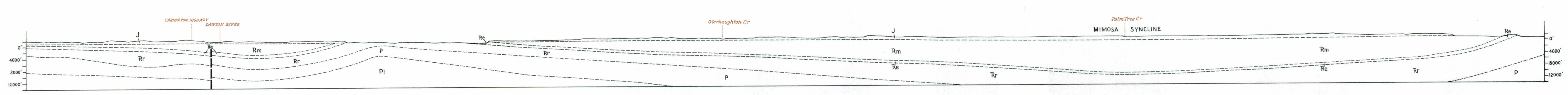


B Detailed reconnaissance - numerous traverses and air-photo interpretation

Geology and compilation, 1963-64, by: V.R. Forbes (G.S.Q.); A.R. Jensen, R.G. Mollan, C.M. Gregory, N.F. Exon (B.M.R.). Geology of Arcadia area based on mapping by Shell (Queensland) Development Pty Ltd, 1944.
Cartography by: Geological Branch, B.M.R.
Drawn by:

Sections
Scale
Upper $\frac{V}{H} = 8$
Lower $\frac{V}{H} = 1$





TAROOM
SHEET SG 55-8

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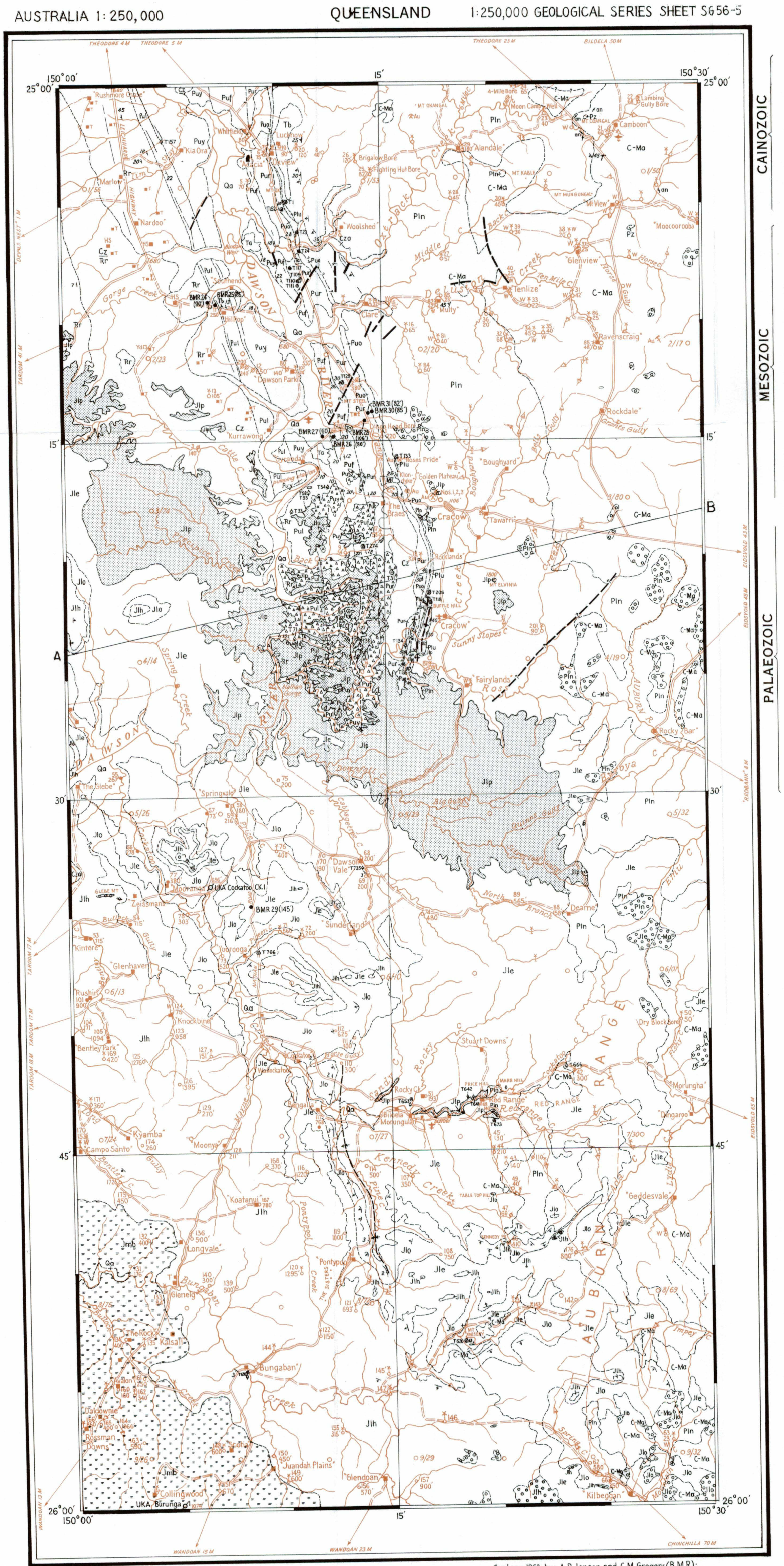
MUNDUBBERA
WESTERN PART

AUSTRALIA 1: 250,000 QUEENSLAND 1:250,000 GEOLOGICAL SERIES SHEET SG56-5

PLATE 5



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Geology, 1963, by: A.R.Jensen and C.M.Gregory (B.M.R.); V.R.Forbes (G.S.Q.)
Compiled, 1963, by: A.R.Jensen and C.M.Gregory (B.M.R.); V.R.Forbes (G.S.Q.)
Drawn by: E.Feeken

Reference

Era	Period	Formation	Symbol	Description
CAINOZOIC			Qa	Alluvium
			Cz	Soil, sand
	TERTIARY			Laterite
			Ta	Silicified gravel, clay
			Tb	Basalt
MESOZOIC			Mi	Gabbro
	MIDDLE JURASSIC	Birkhead Formation	Jmb	Calcareous lithic sandstone, carbonaceous shale, coal
	LOWER TO MIDDLE JURASSIC	Hutton Sandstone	Jlh	Quartzose sandstone, sublabile argillaceous sandstone
	LOWER JURASSIC	Evergreen Formation	Jle	Fine sandstone, argillite, mudstone, coal
			Jlo	Pelletal or oolitic chamositic rock with minor mudstone, sandstone and shale, cropping out as oolitic limonite and concretionary banded ironstone
		Precipice Sandstone	Jlp	Quartzose sandstone, siltstone, argillite
				Silicified sedimentary rocks
	TRIASSIC	Clematis Sandstone	Re	Argillaceous quartzose sandstone, sublabile sandstone, conglomerate (section only)
		Rewan Formation	Rr	Brown mudstone, lithic sandstone, conglomerate
	CARBONIFEROUS TO MESOZOIC	Auburn Complex	C-Ma	Granodiorite, minor diorite; diorite, aplite, dacite and andesite dykes
PALAEOZOIC	UPPER PERMIAN	Baralaba Coal Measures	Pul	Carbonaceous mudstone, feldspatholithic sandstone, coal, conglomerate
		Gyranda Formation	Puy	Lithic sandstone, mudstone, minor conglomerate, tuff
		Back Creek Group: Flat Top Formation	Puf	Blue and brown mudstone, buff argillite, sandy tuffaceous siltstone
		Back Creek Group: Barfield Formation	Pur	Grey mudstone, lithic sandstone, concretionary limestone, lapilli tuff, andesite
		Back Creek Group: Oxtrack Formation	Puo	Coquinite, calcareous mudstone, silicified limestone
	LOWER PERMIAN	Back Creek Group: Buffel Formation	Plu	Coquinite, silicified limestone, conglomerate
		Camboon Andesite	Pln	Andesite, dacite, rhyolite, pyroclastics, conglomerate
			Pz	Granulite, meta-quartzite

Geological boundary
Syncline
Anticline
Monocline
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

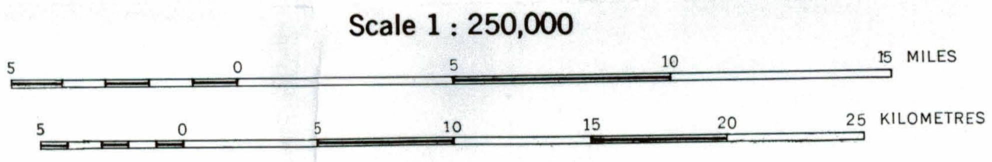
20 Strike and dip of strata
Dip < 15° } air-photo interpretation
Trend lines } air-photo interpretation
Joint pattern } air-photo interpretation
45 Platy flow, inclined
Macrofossil locality
Plant fossil locality
Fossil wood locality
T 642 Fossil collection number
an Andesite dyke

Mine
Mine, not being worked
Open cut
Prospect
Au Gold
Bore } 34/45′ Field reference number / Depth
W Well
Artesian bore
Dry bore
Windpump
Earth dam
T Earth tank

BMR27(60′) Shallow drill hole (number and depth)
Dry oil well

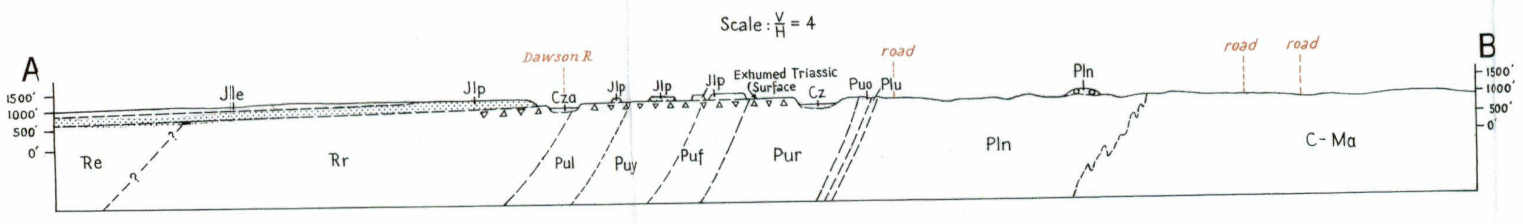
Road
Vehicle track
Track
"Kintore" Homestead
Building
Landing ground
1074′ Altitude in feet - instrument levelled } datum: mean sea level
680 Altitude in feet - barometric } datum: mean sea level
9/32 Photo-centre point - run/number

Scale 1 : 250,000

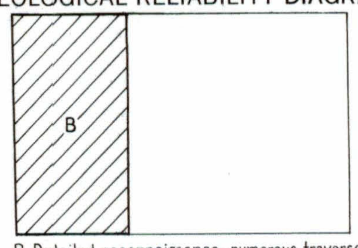


Section

Scale: V/H = 4

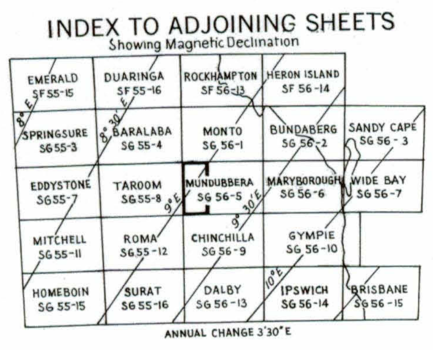


GEOLOGICAL RELIABILITY DIAGRAM



B Detailed reconnaissance - numerous traverses, air photo interpretation

INDEX TO ADJOINING SHEETS
Showing Magnetic Declination



MUNDUBBERA
SHEET SG 56-5