COMMONWEALTH OF AUSTRALIA

STATE OF QUEENSLAND

REPORT No. 123

Geology of the Springsure 1:250,000 Sheet Area, Queensland

BY

R. G. MOLLAN, J. M. DICKINS, and N.F. EXON, Bureau of Mineral Resources and A. G. KIRKEGAARD, Geological Survey of Queensland

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DEPARTMENT OF NATIONAL DEVELOPMENT

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SUMMARY

The Springsure Sheet area covers parts of the Drummond, Bowen, and Great Artesian Basins.

Basement to the Drummond Basin is the Anakie Metamorphics and granite, which are probably of Lower Palaeozoic age, and crop out in two inliers in the Telemon Anticline. The inliers represent part of the mainly buried northern extension of the Nebine Ridge, which was onlapped by a sequence of andesitic volcanics with lenses of lower Middle Devonian coralline limestone near the top, the Dunstable Volcanics. The Dunstable Volcanics form an upfaulted inlier in the Nogoa Anticline.

The Drummond Basin contains 14,000 feet of sediments and volcanics ranging from Upper Devonian to Lower Carboniferous. The Silver Hills Volcanics, which contain about 500 feet of sediments in the Nogoa Anticline, unconformably overlap the Dunstable Volcanics, Anakie Metamorphics, and granite; the Silver Hills Volcanics are in turn unconformably overlapped by the Telemon Formation. The Telemon and Ducabrook Formations comprise about 11,000 feet of interbedded conglomerate, sandstone, and shale containing abundant tuffaceous material and reworked volcanic detritus. The two formations are separated by about 1000 feet of flaggy quartz sandstone (Raymond Sandstone) at the base of which is a lenticular quartz conglomerate (Mount Hall Conglomerate). The Raymond Sandstone and Mount Hall Conglomerate are disconformably overlain by the Ducabrook Formation in the southern part of the Telemon Anticline.

The sediments in the Drummond Basin have been folded into broad north-trending anticlines which are increasingly more complex and intensely faulted to the east; the most easterly structures are possibly overthrust to the west. The Nogoa Anticline continues farther south than was previously thought; it is a major axis related to the Nebine Ridge, which influenced sedimentation from Carboniferous to Jurassic times. A period of folding in early Upper Carboniferous time followed the deposition of the Lower Carboniferous Ducabrook Formation and preceded the deposition of about 2000 feet of glacigene sediments of the Joe Joe Formation, which contains Upper Carboniferous plants and spores. The Joe Joe Formation thins to the east owing to erosion before the Lower Permian Colinlea Sandstone was laid down.

The Permian-Triassic Bowen Basin is represented by two major structural and depositional provinces: the Denison Trough in the east and the Springsure Shelf in the west. The Denison Trough is a Lower Permian downwarp along the western margin of the Bowen Basin in which about 12,000 feet (5000 ft exposed) of interbedded marine and non-marine dominantly clastic sediments accumulated during almost uninterrupted sedimentation. The type of sedimentation varied; periods of fluviatile-deltaic sandy sedimentation alternated with periods of marine, often restricted, silty sedimentation. A sheet of mainly fluviatile sand about 500 feet thick (Colinlea Sandstone) slowly accumulated on the relatively stable Springsure Shelf during upper Lower Permian time.

Mild diastrophism at the end of the Lower Permian altered the nature of the deposition so that the Denison Trough and Springsure Shelf were no longer distinct depositional provinces. Erosion of Lower Permian sediments in the southern and eastern parts of the trough preceded a widespread marine transgression, marking the onset of Upper Permian sedimentation. The Lower Permian sediments are disconformably to unconformably overlain by about 4500 feet of Upper Permian marine and paludal sediments, and Triassic non-marine red-beds and sandstone; breaks in deposition during this period are evident in some areas.

The Permian-Triassic rocks in the Denison Trough area have been folded into three major north-trending anticlines: the Springsure, Serocold, and Consuelo Anticlines. The folds probably reflect mild orogeny in Upper Permian to late Triassic times, and were formed by compression from the east.

The Permian-Triassic rocks in the Springsure Shelf mainly dip gently to the south; several north-trending folds are superimposed on folds in the underlying rocks of the Drummond Basin. Similarly, the Colinlea Sandstone has been block-faulted near the Nogoa Anticline, as a consequence of movement along faults in the Drummond Basin sequence. The Colinlea Sandstone overlaps older units along the southerly extension of the Nogoa Anticline.

The Lower Jurassic sequence of the Great Artesian Basin comprises about 1000 feet, mainly of quartz sandstone separated by thin beds of lutite and ironstone; the sequence is conformably overlain by the Middle Jurassic Birkhead Formation in the extreme southwest. The basal part of the Lower Jurassic sequence, the Precipice Sandstone, rests unconformably on Triassic formations in the east, but to the west it rests disconformably on the Triassic Moolayember Formation.

The position of the Nebine Ridge, inferred from a positive Bouguer gravity anomaly, approximately marks a lithological facies change in Lower Jurassic sedimentation; the ridge also coincides with a very broad anticlinal warp which interrupts the gentle regional southwesterly dip of the Jurassic sequence.

A sheet of Tertiary basalt interbedded with pyroclastics and sediments north of Springsure town covers much of the eastern half of the Sheet area. The basalt sheet has collapsed where the soft underlying formations have been eroded. Tertiary basaltic plugs and dykes intrude Carboniferous to Jurassic rocks. The Tertiary basalt and the dome-forming intermediate and acid volcanics (Minerva Hills Volcanics) are comagmatic. The Joe Joe Formation near the western boundary of the Sheet area, the Permian formations in the Springsure Anticline, and the Tertiary sediments east of the Rewan Syncline are lateritized; Tertiary basalt overlies the lateritized Permian sediments. Boulders of silicate ('billy') in the scree have probably been derived from siliceous cappings on sandstone formations overlain by Tertiary basalt.

Drilling for oil and gas in the Permian sediments of the Denison Trough has yielded petroliferous gas, but it has not yet been commercially developed. The trough is the most promising province for oil and gas accumulations. The Drummond Basin and the Springsure Shelf contain some suitable structural traps and reservoir rocks for oil and gas, and the shale in both provinces is a potential source rock. Coal seams are present in the Blackwater Group, and bentonitic clays in the Black Alley Shale.

INTRODUCTION

A joint Bureau of Mineral Resources and Geological Survey of Queensland field party mapped the Springsure Sheet area in 1963 as part of a systematic plan, begun in 1960, to map the Bowen Basin and to assist in the search for oil. This Report and maps are based mainly on field work done between May and October 1963 by R.G. Mollan and N.F. Exon of the Bureau of Mineral Resources, and A.G. Kirkegaard of the Geological Survey of Queensland (Mollan, Exon, & Kirkegaard, 1964). J.M. Dickins and E.J. Malone spent several weeks with the field party. In June 1962 the Permian section in the eastern part of the Sheet area was examined by E.J. Malone, J.M. Dickins, and P.R. Evans, accompanied by A. Fehr of the Institut Francais du Petrole. Mollan and Dickins spent several weeks in 1964 measuring additional sections in the Serocold Anticline and in the same year Mollan mapped the Serocold and Springsure Anticlines in the Emerald and Eddystone Sheet areas (Pls 7A, 7B). In 1964, Mollan and V.R. Forbes mapped the Jurassic units in the southern part of the Springsure Sheet.

This Report is essentially a revision of Mollan, Exon, & Kirkegaard (1964) by Mollan in the light of new data from field work, palaeontological and petrological investigations, and drilling.

The Springsure Sheet area is bounded by longitudes 147°E. and 148°E. and latitudes 24°S. and 25°S.; the eastern boundary is 170 miles from the coast near Rockhampton. Springsure, the only town in the area, is about 200 miles from Rockhampton by road and rail. It is served by a branch railway from Emerald and joined by roads to Emerald, Rolleston (Springsure-Duaringa Highway), and Tambo (Central Western Highway). In the northern half of the Sheet area there is a network of graded roads and station tracks, but in the south there are very few tracks.

Climate is subtropical. The area is situated outside the maritime influence, and consequently does not receive reliable rain. The annual rainfall is extremely variable; the average ranges from 24 inches in the west to 28 inches in the east (Fig. 1)*. Most of the rain falls in January, February, and March, with summer storms from October to December. The rest of the year is usually dry. The summer months are very hot and the winter months are warm during the day and frequently cool to frosty at night.

The vegetation is dominantly of the savannah type, with tall grass and an even cover of timber, varying in density and type with the soil and underlying rock: the black basaltic soils support grassy downs, and the sandstone commonly has a dense cover of timber. Parts of the western half of the Sheet area have a dense cover of brigalow scrub.

Cattle raising is the main industry, but several stations run sheep. Wheat and other grain crops are grown in some areas, notably near Springsure, where the land holdings are small. Several large holdings in the western half of the Sheet area are being subdivided and cleared of scrub.

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* Isohyets shown in Figure 1 are based on data contained in 'Climate' map sheet and booklet, Fitzroy Region, Queensland: Resources Series produced by Department of National Development, Resources Information and Development Branch, Canberra, 1965.

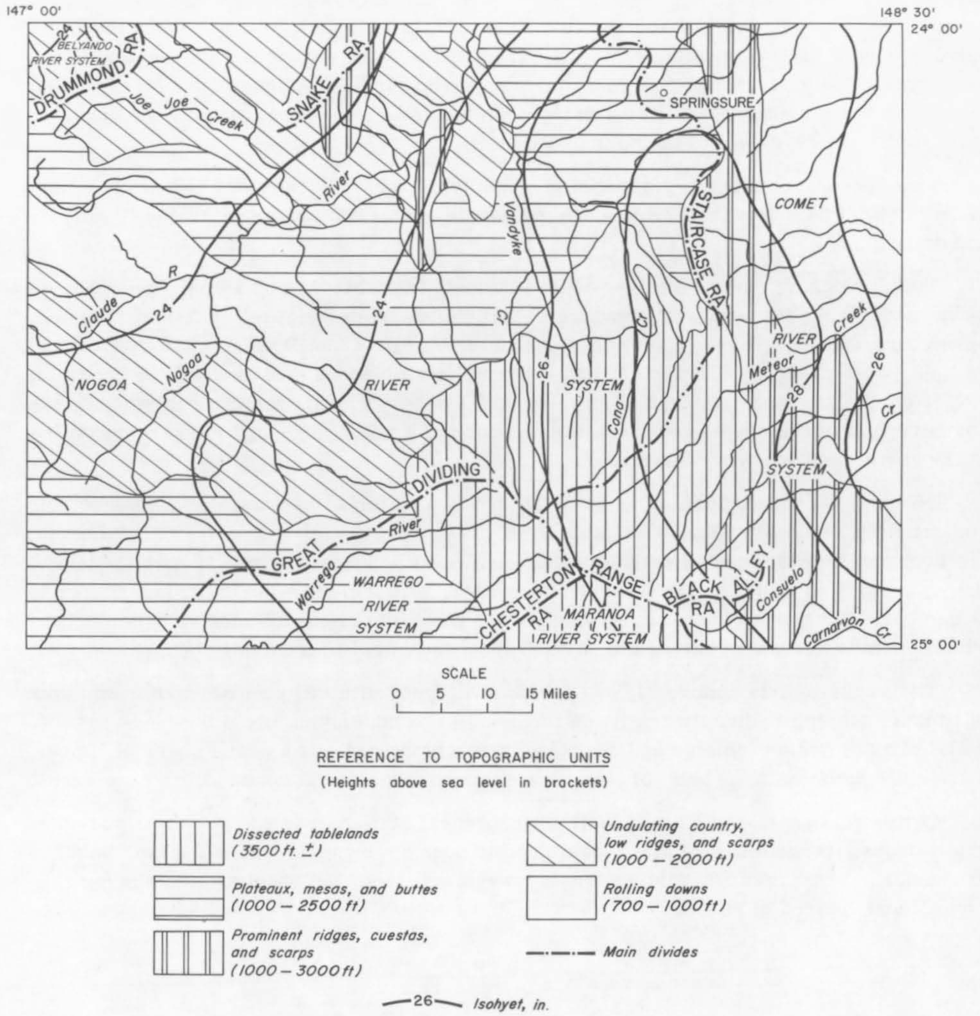
147° 00'
148° 30'
24° 00'
25° 00'
24
BELYANDO RIVER SYSTEM
DRUMMOND RA
Joe Joe Creek
SNAKE RA
River
Vandyke Cr
SPRINGSURE
STAIRCASE RA
COMET
Claude R
24
NOGOA
Nogoa
RIVER
24
26
SYSTEM
Cona- Cr
RIVER
Meteor
Creek
28
26
Cr
SYSTEM
DIVIDING
GREAT
River
Warrego
WARREGO RIVER SYSTEM
CHESTERTON RA
RANGE
MARANOA RIVER SYSTEM
BLACK ALLEY RA
Consuelo
Carnarvon Cr
SCALE
0 5 10 15 Miles
REFERENCE TO TOPOGRAPHIC UNITS
(Heights above sea level in brackets)
Dissected tablelands (3500 ft. ±)
Plateaux, mesas, and buttes (1000 – 2500 ft)
Prominent ridges, cuestas, and scarps (1000 – 3000 ft)
Undulating country, low ridges, and scarps (1000 – 2000 ft)
Rolling downs (700 – 1000 ft)
Main divides
26 Isohyet, in.

Figure 1

The Sheet area is almost covered by two sets of air-photographs taken by Adastra Airways Pty Ltd, at a scale of about 1:85,000. The geology was compiled at photo-scale and reduced to 1:250,000 (Pl. 6). A 1:250,000 photogeological map by W.J. Perry (BMR), and J.Y. Scanvic, B. de Lassus Saint-Genies, and R. Richard of the Institut Francais du Petrole (Richard, 1963), was available before field work began.

Fifteen shallow holes were drilled for stratigraphic information in 1963, and 8 in 1964; another hole, BMR 45 Eddystone, lies just outside the Sheet area (Pl. 7B). The results of the drilling are reported in Malone (1963) and Mollan, Exon, & Forbes (1965b). Arman (1965b) has made a petrological study of some of the 1963 drill cores.

Sections S2, S3, S5, S7, S11, S13, S15, S16, S18-22, S29, S30, and S32-35 were measured by Abney level; S4, S6A, and S6B by Abney level and barometer; S23, S24, S26, and S28 by Abney level and distances measured on the air-photographs; S14 by Abney level and distances measured on the air-photographs with corrections for elevation; S25 and S31 by Abney level and estimation; S8-S9 by Abney level and chain, pace, and compass; S12 by Abney level, pace, and compass; S10, S17, and S27 by pace and compass; and S1 by chain.

Physiography

The area ranges in elevation from about 700 feet above sea level in the northeast corner to 3340 feet in the Black Alley Range in the southeast. Much of the eastern part of the Great Dividing Range is over 3000 feet. Five topographic units have been recognized (Fig. 1):

A dissected tableland, known as Buckland Tableland, is the most prominent topographic unit. It is broken by broad valleys which are bounded by steep scree-covered slopes.

Small plateaux, mesas, and buttes are characterized by white cliffs of sandstone and acid volcanic rocks (near Springsure); the mesas are separated by sandy flats in the west, and heavy dark soil flats in the northeast. Streams have cut sinuous gorges in the sandstone plateaux in the west.

Prominent ridges, cuestas, and scarps form three regions which are dissected by transverse watercourses.

Undulating country is characterized by small ridges and scarps which break the topographic monotony of these regions; the streams have fairly mature profiles.

Rolling downs have a heavy dark soil, which supports a thick cover of grass and a few trees; the streams meander across small floodplains.

The drainage system and main divides are shown in Figure 1. The Great Dividing Range separates the streams flowing north into the Fitzroy River from those flowing south into the Darling River. The main watercourses to the north are the Nogoa and Claude Rivers, and Vandyke, Cona, Meteor, Consuelo, and Carnarvon Creeks, which are perennial, except during prolonged dry spells. The water in Carnarvon, Consuelo, and Meteor Creeks is notably clear and soft. To the south of the Great Dividing Range, the upper reaches of the Warrego and Maranoa Rivers lie in the Sheet area.

Previous Investigations

Geological work. Much geological work in the area has been done in the search for oil. Before 1930 several geologists made reconnaissance surveys of parts of the area, and since then numerous geologists have studied the Permian rocks in the Springsure and Serocold Anticlines, and a few have studied the Devonian-Carboniferous rocks in the Telemon and Nogoa Anticlines.

Jack (1895) recorded marine fossils at many localities; Richards (1918a) described the volcanic rocks around Springsure; Jensen (1926) made a geological reconnaissance of the Sheet area, and recognized the Serocold Anticline. Reid (1930) mapped the Serocold Anticline and subdivided the Permian rocks into formations; Reeves (1936, 1947) revised and extended this mapping. The detailed work by Shell (Queensland) Development Pty Ltd is recorded in several unpublished reports (Schneeberger, 1942; Woolley, 1943; SQD, 1952); the first edition of the Springsure 4-mile Geological Sheet and the explanatory notes by Hill (1957) were based mainly on the work of Shell. Whitehouse (1955) mapped the Mesozoic rocks in the Sheet area. Patterson (1955, 1956) mapped the Springsure Anticline in detail, and Webb (1956) reviewed the results of exploratory wells penetrating Permian sections and incorporated Patterson's stratigraphy. Phillips (1959; in Hill & Denmead, 1960) mapped the Springsure and Serocold Anticlines. Laing (1961) mapped Reids Dome, and Madden (1960) mapped the Permian of the Springsure Shelf.

Derrington (1962) and Malone (1964) have discussed the tectonic framework of the Bowen Basin. Cundill, Meyers, & Associates (1963, 1965), Cundill & Meyers (1964), and Power (1966) have studied the Permian sequence in the Denison Trough.

Palaeontological work. The rich invertebrate faunas found in parts of the Permian sequence have attracted much interest. In recent years Fletcher (1945a,b), Dickins (1961), and Runnegar (1965) have described pelecypods; Campbell (1953, 1959, 1960,1961, 1965) has described the fauna from the Ingelara Formation and spiriferoids and terebratuloids; Maxwell (1954) has described Strophalosia; Hill (1943, 1957, & in unpubl. reps by Shell (Queensland) Development Pty Ltd and other companies) has identified marine invertebrate faunas from Permian and pre-Permian rocks; Dear (app. in Mines Administration Pty Ltd, 1962a & other unpubl. reps) has identified fossils from oil wells. Some invertebrate fossils are illustrated in Hill & Woods (1964). Runnegar (1965; 1967) and R.E. Wass are currently describing Permian pelecypods and bryozoans.

Four faunal subdivisions have been recognized by Dickins (1964; & in press) in the marine Permian (see App. 1). The age of the marine sedimentation is considered in detail in Dickins (in press).

Evans (1964a,b, 1965, 1966, & two reports in prep.) has made palynological studies in the Palaeozoic and Mesozoic sections.

Geophysical work. The results of a gravity survey of a large part of the Bowen Basin by Starkey & Warren (1959) have been reviewed by Robertson (1961). The results of this survey in the Springsure Sheet area, and a survey by United Geophysical Corporation (1964), are shown in Figure 10.

An airborne magnetometer survey of the Springsure Sheet area was carried out in 1962; the results are given in a Bureau of Mineral Resources map (1964) and in Figure 11.

A reflection seismic survey was carried out in the eastern part of the Springsure Sheet by Geophysical Service International (1962), as part of a larger survey for Mines Administration Pty Ltd in the Baralaba Sheet area. A structural trend map, interpreted from the seismic results, is reproduced in Figure 12.

Exploratory drilling for oil and gas. Seven wells have been drilled in the Springsure Sheet area in the search for oil (Table 1), and many other wells have been drilled to the east and south. Lithological and electric logs, showing zones with hydrocarbons, in most of the wells in the Springsure area, and many wells outside the Sheet, are shown in Plates 8A and 8B; data from the wells are summarized in Table 1.

TABLE 1 : OIL AND GAS EXPLORATION WELLS

	Well	Year Drilled	Subsidized	Total Depth (ft)	Hydrocarbons (see Pls 8A & 8B)	Status	Reference
Wells outside the Springsure Sheet area shown on Plates 8A & 8B.	AOE No. 1 (Reids Dome)	1954	No	9060	Minor gas and oil shows in top 3000'	Abandoned	Geol. Surv. Queensland (1960)
	AOE No. 2 (Reids Dome)	1955	No	4060	None	Abandoned	Ibid (1960)
	AOE No. 3 (Consuelo)	1955	No	4437	None	Abandoned	Ibid (1960)
	AFO Inderi No. 1	1963	Yes	5433	Gas shows: 1818-1901', 800,000 cfd	Abandoned	Mines Administration Pty Ltd (1963a); Arman (1965b)
	AFO Arcturus No. 1	1964	Yes	6203	Gas shows: 1690-1758', 3.6 Mmcfd; 1860-1920', 1.6 Mmcfd; 1920-2120', 1.0-1.25 Mmcfd; 2510-80', 400-900 Mcfd	Gas well suspended	Ibid (1965a)
	AFO Arcturus No. 2	1964	No	3651	None	Abandoned	Geol. Surv. Queensland (1965)
	AFO Yandina No. 1	1965	Yes	2558	None	Abandoned	Mines Administration Pty Ltd (1965b)
Wells in the Springsure Sheet area	SQD No. 1 (Morella)	1950-51	No	4634	Trace of oil and gas at about 3000'	Abandoned	Geol. Surv. Queensland (1960)
	AAO No. 7 (Arcadia)	1957	No	3280	Small gas show at 2919½'	Abandoned	Derrington (1957)
	AAO Glentulloch No. 1	1961	Yes	4083	Many gas shows, much gas mixed with water; open hole test, 7.5 Mmcfd	Abandoned	Mines Administration Pty Ltd (1962a)
	AAO Westgrove No. 1	1962	Yes	6442	Minor gas shows	Abandoned	Ibid (1962b)
	AAO Killoran No. 1	1962	Yes	3250	Minor gas show	Abandoned	Ibid (1962c)
	AAO Kildare No. 1	1963	Yes	5724	Minor gas shows	Abandoned	Ibid (1963b)
	AFO Bandanna No. 1	1963	Yes	4041	Minor gas shows	Abandoned	Ibid (1963c)
	AFO Purbrook No. 1	1963	Yes	4949	Minor gas-oil show at 3816-25'	Abandoned	Ibid (1963d)
	AFO Rolleston No. 1	1963-64	Yes	9508	Many gas shows: open flow potential, 2945-80', 43 Mmcfd, condensate also; 1836-1902', 1.38 Mmcfd	Gas well suspended	Ibid (1964)
	Planet Warrinilla No. 1	1963	Yes	6701	Many gas shows: 3361-82', 108-88 Mcfd; 3361-96', 10-0 Mcfd; 4617-209', 175-140 Mcfd	Abandoned	Planet Exploration Co. Pty Ltd (1963)
	Planet Warrinilla North No. 1	1963	Yes	6879	Many gas shows: 3722-813', 65 Mcfd; 4005-30', 5 Mcfd; 4027-62', 112 Mcfd; 4061-120', 10 Mcfd; 4535-53', 44 Mcfd; 5510-75', 44-102 Mcfd; 5574-644', 250-162 Mcfd; minor oil shows also	Abandoned	Meyers (1963)
	Planet Tooloombilla No. 1	1964	Yes	1750	None	Abandoned	Meyers (1964a)
	Planet Crystalbrook No. 1	1964	Yes	2061	None	Abandoned	Ibid (1964b)
	Planet Warrong No. 1	1964	Yes	3579	None	Abandoned	Ibid (1964c)
	Marathon-Continental Glenhaughton No. 1	1963-64	Yes	9418	Minor gas shows	Abandoned	Marathon Petroleum Aust. Ltd (1964)

Final reports on the wells subsidized by the Commonwealth Government are available at the Bureau of Mineral Resources. Summary reports on unsubsidized wells are also available (Geol. Surv., Queensland, 1960-65).

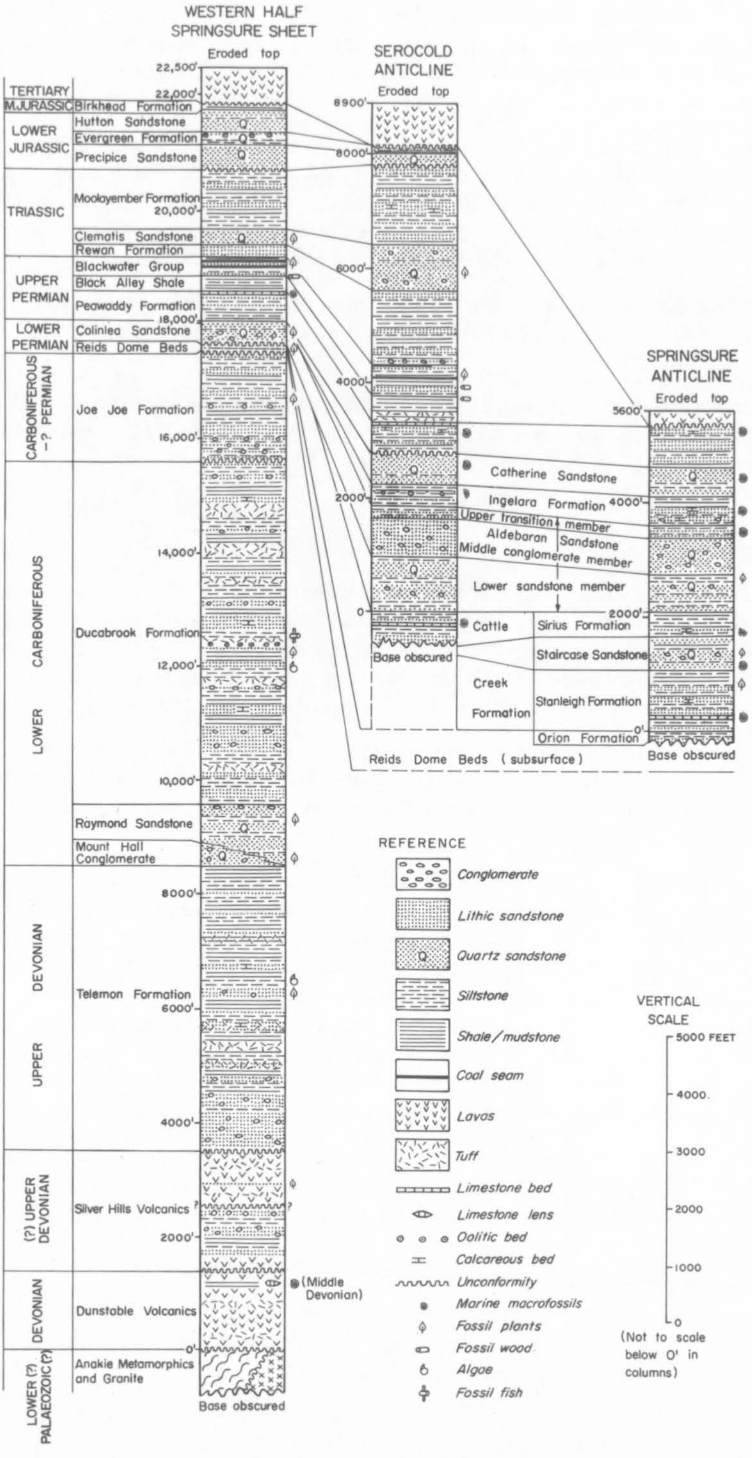
WESTERN HALF
SPRINGSURE SHEET
Eroded top
22,500'
22,000'
20,000'
18,000'
16,000'
14,000'
12,000'
10,000'
8000'
6000'
4000'
2000'
0'
Base obscured
TERTIARY
M.JURASSIC
LOWER JURASSIC
TRIASSIC
UPPER PERMIAN
LOWER PERMIAN
CARBONIFEROUS –? PERMIAN
LOWER CARBONIFEROUS
UPPER DEVONIAN
(?) UPPER DEVONIAN
DEVONIAN
LOWER (?) PALAEOZOIC (?)
Birkhead Formation
Hutton Sandstone
Evergreen Formation
Precipice Sandstone
Moolayember Formation
Clematis Sandstone
Rewan Formation
Blackwater Group
Black Alley Shale
Peawaddy Formation
Colinlea Sandstone
Reids Dome Beds
Joe Joe Formation
Ducabrook Formation
Raymond Sandstone
Mount Hall Conglomerate
Telemon Formation
Silver Hills Volcanics
Dunstable Volcanics
Anakie Metamorphics and Granite
(Middle Devonian)
?
SEROCOLD ANTICLINE
Eroded top
8900'
8000'
6000'
4000'
2000'
0
Base obscured
Catherine Sandstone
Ingelara Formation
Upper transition member
Aldebaran Sandstone
Middle conglomerate member
Lower sandstone member
Cattle Creek Formation
Sirius Formation
Staircase Sandstone
Stanleigh Formation
Orion Formation
Reids Dome Beds (subsurface)
SPRINGSURE ANTICLINE
Eroded top
5600'
4000'
2000'
0'
Base obscured
Q
REFERENCE
Conglomerate
Lithic sandstone
Quartz sandstone
Siltstone
Shale/mudstone
Coal seam
Lavas
Tuff
Limestone bed
Limestone lens
Oolitic bed
Calcareous bed
Unconformity
Marine macrofossils
Fossil plants
Fossil wood
Algae
Fossil fish
VERTICAL SCALE
5000 FEET
4000.
3000
2000
1000
0
(Not to scale below 0' in columns)

Figure 2

STRATIGRAPHY

Figure 2 presents generalized stratigraphic columns from outcrop in the Springsure Sheet area and shows suggested stratigraphic relationships. Numerous measured sections, mainly in the Permian, are presented in Figures 4, 5, 6, 7, and 8 and Plates 9A and 9B. Reference for the sections constitutes Plate 10.

Plates 7A and 7B are a detailed map, at 1:125,000 scale, of the Springsure, Serocold, and Consuelo Anticlines; the map covers new mapping of the Springsure and Serocold Anticlines in the Emerald and Eddystone Sheet areas, and a new informal threefold division of the Aldebaran Sandstone. Localities of measured sections and fossil collections (Apps 1, 2, 3, 4) not covered by this map are shown in Plate 6.

Subsurface correlation of Permian and Triassic units in the eastern part of the Springsure Sheet area and in areas to the east and south is discussed separately, and illustrated in Plates 8A and 8B.

The structure and the main depositional provinces are illustrated in Figures 10, 11, and 12. Informal nomenclature has been adopted where further work may clarify the stratigraphy.

LOWER PALAEOZOIC (?)

Anakie Metamorphics

The oldest rocks in the area are the metamorphics which crop out in a small inlier, about 3/4 mile wide and 3 miles long, at the southern end of the Telemon Anticline. They were first noted by Jensen (1926), and subsequently mapped by Shell (SQD, 1952). The rocks are correlated with the Anakie Metamorphics (Reid, 1936) in the Emerald and Clermont Sheet areas, because of the similarity in lithology and age relationships.

The inlier is an area of undulating country. On the air-photographs the gneiss underlies fairly open thinly timbered country which has a light tone; the other metamorphic rocks are difficult to distinguish from the surrounding Telemon Formation and Silver Hills Volcanics.

Much of the inlier is covered by soil. The gneiss is well exposed in the western half and in a small area along the eastern margin. It is a strongly foliated coarse quartz-feldspar-mica gneiss apparently interbedded with garnetiferous muscovite schist. There is a belt of poorly exposed biotite-quartz phyllite and schist in the centre of the inlier. The northern margin consists of sheared diorite and other igneous rocks. Some of the rocks have been described by B.R. Houston (app. 3 in Mollan et al., 1964). The foliation in the gneiss and the schistosity in the phyllite have a northeasterly trend, parallel to the long axis of the inlier. Foliation and bedding dips are to the southeast. The contacts between the gneiss, phyllite, and sheared diorite are obscured.

The metamorphic rocks are unconformably overlain by the Silver Hills Volcanics and Telemon Formation; the contacts are concealed by soil, and are probably faulted in places. The Anakie Metamorphics are probably intruded by foliated granite which crops out along the eastern margin of the inlier.

The Anakie Metamorphics are probably Lower Palaeozoic because they are unconformably overlain by the Silver Hills Volcanics, which are probably Upper Devonian. However, muscovite schist from the inlier has been dated as late Devonian or early Carboniferous by the K/Ar method (A.W. Webb, App.7).

The inlier forms part of the Nebine Ridge, which has been shown by the gravity survey (Fig. 10) to cross the centre of the Sheet area from south to north; the ridge extends from the Nebine Ridge of Hill (1951) in the south to the Anakie Inlier in the north (Veevers, Mollan, Olgers, & Kirkegaard, 1964a; Veevers, Randal, Mollan, & Paten, 1964b).

Granite

The two outcrops of granite in the centre of the Telemon Anticline form part of the inlier. The larger, northern outcrop of massive granite is poorly exposed; the smaller outcrop of foliated granite lies in the eastern margin.

The massive granite forms gently undulating country with an even cover of timber. Deep weathering has produced a coarse sandy soil. The granite has a light tone on the air-photographs similar to that of the Silver Hills Volcanics. The granite contains varying proportions of biotite and hornblende. Several partly granitized basic xenoliths were noted. The trend of foliation is parallel to the foliation in the Anakie Metamorphics.

The foliated granite probably intrudes the Anakie Metamorphics; the massive granite appears to be overlain by the Telemon Formation and Silver Hills Volcanics. The massive granite has been dated as Ordovician by the K/Ar method (App. 7). If, as the field evidence suggests, it postdates the metamorphic rocks, one of the isotopic dates at least is suspect.

MIDDLE DEVONIAN

Dunstable Volcanics

The term Dunstable Formation, as used by Hill (1957) in place of Shell's Dunstable Series (SQD, 1952), applied to all the rocks exposed below the Telemon Formation in the Nogoa Anticline. The Dunstable Formation of Hill (1957) has been separated into two unconformable units - the Dunstable Volcanics and Silver Hills Volcanics. The Dunstable Volcanics form a faulted northeast-trending inlier in the northern part of the Nogoa Anticline about half a mile northwest of Telemon homestead (Fig. 3). The area of outcrop is designated as the type area. The name is derived from Dunstable Telephone Office at Telemon homestead.

The Dunstable Volcanics form a belt of hilly country which is covered by rubble of tough green volcanic rocks. They are resistant, and readily distinguished from the soft and relatively deeply weathered Silver Hills Volcanics.

The Dunstable Volcanics comprise indurated green andesitic lavas and pyroclastics. Splintery black and olive-green cherty shale and two lenses of sheared and partly reconstituted coralline limestone are present near the top of the exposed sequence along the western margin of the inlier (see Fig. 3). B.R. Houston has described the petrography of several samples (app. 3 in Mollan et al., 1964). The splintery shale dips steeply to the west, and is vertical in places; the volcanics also dip to the west.

The Dunstable Volcanics probably rest unconformably on the Anakie Metamorphics and are unconformably overlain by the Silver Hills Volcanics. The formation is estimated to be about 1500 feet thick, but the base and top are not exposed. The Dunstable Volcanics were probably deposited only on the flanks of the Nebine Ridge, and the marine limestones possibly represent fringing reefs. Uplift, associated with faulting, followed the deposition of the unit.

Isolated outcrops of coralline limestone of similar age occur in the Clermont (Douglas Creek Limestone) and Emerald Sheet areas. The age of all three limestones is probably lower Middle Devonian (Hill, 1957; app. 3 in Veevers et al., 1964a; Veevers et al., 1964b, p.7-9), but as the limestones occur near the top, the lower age limit of the formation is uncertain.

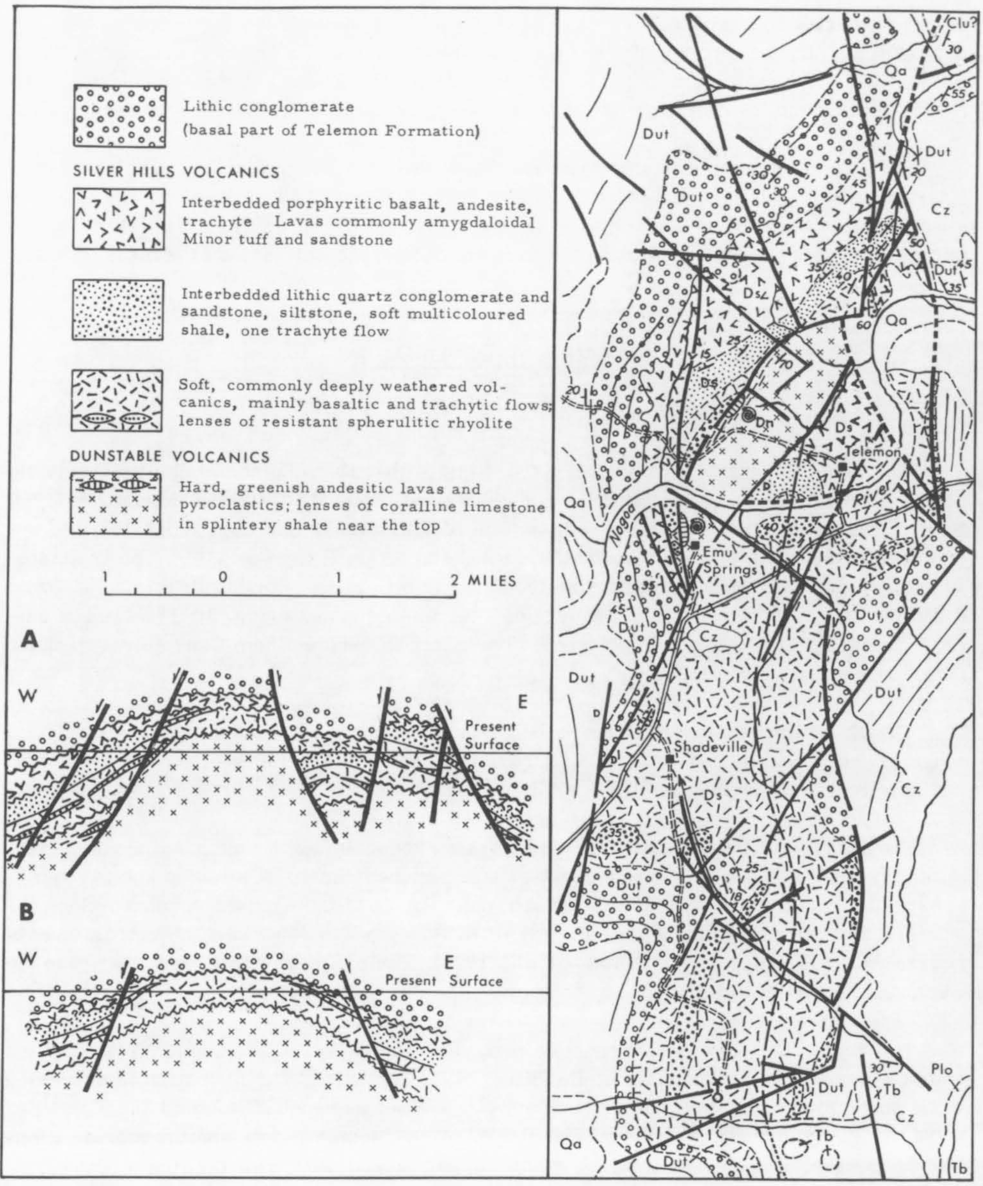
Lithic conglomerate
(basal part of Telemon Formation)
SILVER HILLS VOLCANICS
Interbedded porphyritic basalt, andesite, trachyte Lavas commonly amygdaloidal Minor tuff and sandstone
Interbedded lithic quartz conglomerate and sandstone, siltstone, soft multicoloured shale, one trachyte flow
Soft, commonly deeply weathered volcanics, mainly basaltic and trachytic flows; lenses of resistant spherulitic rhyolite
DUNSTABLE VOLCANICS
Hard, greenish andesitic lavas and pyroclastics; lenses of coralline limestone in splintery shale near the top
1 0 1 2 MILES
A
W
E
Present Surface
B
W
E
Present Surface
Clu?
Qa
Dut
Cz
Ds
Dn
Telemon
Nogoa
River
Emu Springs
Shadeville
Plo
Tb

Figure 3

UPPER DEVONIAN(?)

Silver Hills Volcanics

The Silver Hills Volcanics (Veevers et al., 1964a) crop out in the Nogoa and Telemon Anticlines. In the Nogoa Anticline they unconformably overlie the Dunstable Volcanics. In the Telemon Anticline, the volcanics which were previously mapped as Tertiary basalt (SQD, 1952; Hill, 1957), belong to the Silver Hills Volcanics. The unconformable younger part of the Dunstable Formation of Hill (1957) has been assigned to the Silver Hills Volcanics, because of its similar stratigraphic position; and contrary to the opinions expressed in Veevers et al. (1964a), the unit consists predominantly of volcanics (see Fig. 3) similar to those in the type area, where they range from basalt to rhyolite.

The upper and lower volcanic sequences are separated by sediments. Only the uppermost volcanics are exposed in the Telemon Anticline. The rock types are described in Figure 3; detailed petrographic descriptions are given in Mollan et al. (1964, app. 3). The volcanics are commonly deeply weathered and form rolling country with thick residual dark soil; in the lower sequence lenses of spherulitic trachyte form small cuestas and ridges. The sediments form strike ridges. The volcanics are estimated to be about 1500 feet thick, and the sediments about 500 feet; the total thickness is about the same as in the type area (Veevers et al., 1964a).

Little is known about the environment of deposition of the Silver Hills Volcanics. They probably represent the earliest deposits in the Drummond Basin. The presence of sediments shows that part of the formation was deposited in water, and the presence of spilite in the Telemon Anticline (see Mollan et al., 1964, app. 3) suggests that some of the volcanics were also deposited in water.

In the Telemon Anticline, the Dunstable Volcanics are overlapped by the Silver Hills Volcanics, which rest on the Anakie Metamorphics and granite. In the Nogoa Anticline the boundary between the Silver Hills and Dunstable Volcanics is faulted (Fig. 3). The Silver Hills Volcanics are unconformably overlain by the Telemon Formation.

The volcanic rocks in the core of the Telemon Anticline, which were mapped as Tertiary by Shell geologists (SQD, 1952, p. 42), are now regarded as part of the Silver Hills Volcanics because:

(i) The basalt conglomerate of the Telemon Formation rests unconformably on the volcanics.

(ii) The volcanics are not similar to Tertiary volcanics in the Springsure Sheet area, but are similar to volcanics at the top of the Silver Hills Volcanics in the Nogoa Anticline.

(iii) The volcanics are commonly faulted in contact with the Telemon Formation and are slightly sheared and veined with quartz. Nowhere in the Springsure Sheet area are similar features observed in Tertiary volcanics.

(iv) Sericitized plagioclase phenocrysts from a basalt have been dated by the K/Ar method as Upper Carboniferous (see app. 7).

The Silver Hills Volcanics are possibly Upper Devonian in age.

UPPER DEVONIAN/LOWER CARBONIFEROUS(?)

Telemon Formation

The Telemon Formation (Hill, 1957) was originally named the Telemon Series by Shell (SQD, 1952) after the type area on Telemon pastoral holding. The unit crops out extensively in the Nogoa and Telemon Anticlines and in the Vandyke Anticline. It also

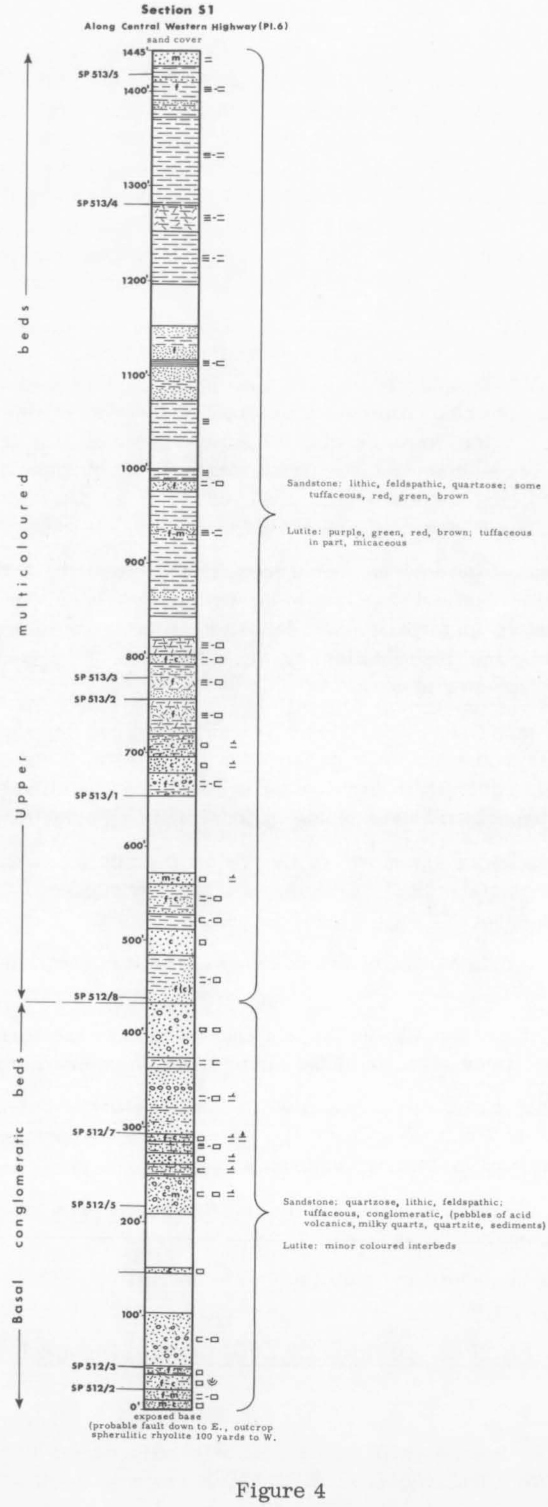
Section S1
Along Central Western Highway (Pl.6)
sand cover
1445'
SP 513/5
1400'
1300'
SP 513/4
1200'
1100'
1000'
900'
800'
SP 513/3
SP 513/2
700'
SP 513/1
600'
500'
SP 512/8
400'
300'
SP 512/7
SP 512/5
200'
100'
SP 512/3
SP 512/2
0'
exposed base
(probable fault down to E., outcrop
spherulitic rhyolite 100 yards to W.
Upper multicoloured beds
Basal conglomeratic beds
Sandstone: lithic, feldspathic, quartzose; some tuffaceous, red, green, brown
Lutite: purple, green, red, brown; tuffaceous in part, micaceous
Sandstone; quartzose, lithic, feldspathic; tuffaceous, conglomeratic, (pebbles of acid volcanics, milky quartz, quartzite, sediments)
Lutite: minor coloured interbeds

Figure 4

crops out extensively to the north in the Emerald and Clermont Sheet areas. A small outcrop north of Springsure town, southeast of St Peter, possibly belongs to the Telemon Formation (see Pl. 6).

The formation was subdivided by Shell into a lower conglomerate 'group' and an upper multicoloured 'group'. The basal conglomeratic beds form low rounded sparsely timbered ridges in contrast to the fairly flat soil and scrub-covered areas formed by the soft upper multicoloured beds. On the air-photographs of the Nogoa Anticline the basal conglomeratic beds have a light tone, in which faint bedding trends can be distinguished, whereas the upper multicoloured beds have a dark tone with clearly defined bedding trends.

The basal conglomeratic beds comprise massive conglomerate and conglomeratic sandstone. The conglomerate is commonly cross-bedded and consists of well rounded pebbles and cobbles of milky quartz, quartzite, schist, and various igneous rocks set in a coarse lithic, feldspathic, tuffaceous matrix. Most of the pebbles and cobbles in the basal conglomerate in the Telemon Anticline consist of volcanics similar to those in the underlying Silver Hills Volcanics. The basal conglomeratic beds are overlain by a thick sequence of interbedded thin soft multicoloured lutites and arenites. A measured section of part of the formation is given in Figure 4. The sediments are commonly cross-bedded and festoon-bedded in units of varying thickness; faint graded-bedding is evident in some sandstone; sole marks and current striations are also present.

Lenticular beds of algal(?) limestone occur throughout the upper part of the formation. The individual algal colonies are commonly spheroidal, dome-shaped, and cylindrical. They are commonly about 6 inches long and 1 inch wide, but range up to 5 feet long by 1 foot wide. The cylinders consist of concentric layers with radial fibres, and several algae are probably represented. The algal limestone is rarely found in situ, and the individual colonies are commonly found overlying heavy black soils, which suggests they have been weathered out of a soft marly rock.

The lower part of the formation has a mainly volcanic provenance, and the upper part a granitic-metamorphic provenance (Table 2). The Drummond Basin was dominantly non-marine during the deposition of the Telemon Formation; algal colonies possibly lived in brackish water, and fish remains have also been identified. Shell (SQD, 1952) consider that the algal(?) limestone represents tufa formed in playas and saltwater lakes. The presence of brecciated lime-mud rocks suggests the desiccation of a calcareous mud with subsequent immersion in a playa or lacustrine environment. Shell report the presence of the branchiopod Leaia, which probably lived in fresh water. The presence of tuff and tuffaceous sediment indicates that explosive volcanic activity persisted along the margins of the basin during deposition of the Telemon Formation; no lavas are present.

The Telemon Formation represents a period of rapidly alternating arenite and lutite deposition. The basal conglomeratic beds thin rapidly to the west; the conglomerate is probably a syntectonic deposit on the margin of the basin, which was derived mainly from the Silver Hills Volcanics to the east.

The Telemon Formation rests unconformably on the Silver Hills Volcanics in the Nogoa and Telemon Anticlines. The unconformity was observed in the northwestern part of the Nogoa Anticline and in the eastern limb of the Telemon Anticline. In the southern part of the Telemon Anticline, the Telemon Formation overlaps the Silver Hills Volcanics and rests on the Anakie Metamorphics.

The Telemon Formation is regarded as Upper Devonian, but possibly ranges into the Lower Carboniferous. The age is based on the following data:

(i) It is separated from fossiliferous lower Middle Devonian sediments by two unconformities and unconformably overlies the Retreat Granite, which has been isotopically dated at 360± 10 m.y. (Webb, Cooper, & Richards, 1963; A.W. Webb, pres.comm.).

TABLE 2 : COMPOSITION OF SEDIMENTS FROM MEASURED SECTION S1 (FIG. 4) IN PART OF THE TELEMON FORMATION

Name	Approximate Height from Base of Section (ft)	Specimen No.	Quartz (including quartz aggregates) (%)	Volcanics (mainly rhyolitic and andesitic) (%)	Sediments Fine recrystallized quartz-mica rock) (%)	Potash Feldspar and Plagioclase (%)	Cement or Groundmass	Other Constituents (%)
Quartz lithic sandstone	1430	SP513/5	60	10	10	15	-	Iron oxide(5), muscovite(1), minor epidote, chlorite, and zircon
Vitric tuff	1280	SP513/4	10	minor	25	5	glassy; 60% terrigenous groundmass	Iron oxide abundant, minor biotite, epidote, and zircon
Calcareous sandstone	775	SP513/3	25	5	15	5	50% calcite	Iron oxide abundant, minor muscovite, biotite, and epidote
Calcareous quartz lithic sandstone	750	SP513/2	30	20	-	10	35% calcite	Iron oxide(5), minor muscovite, biotite, zircon, and tourmaline
Lithic sandstone	650	SP513/1	30	15	30	15	-	Iron oxide(5), muscovite (2), epidote(2), minor biotite (metamorphic?) and chlorite
Quartz lithic sandstone	440	SP512/8	55	10	20	10	-	Iron oxide(3), minor muscovite, biotite (metamorphic?), epidote, and chlorite
Quartz sandstone	290	SP512/7	75	10	5	5	-	Minor iron oxide, biotite (metamorphic?), epidote, and chlorite
Quartz lithic sandstone	220	SP512/5	70	minor	20	5	-	Muscovite(1), minor iron oxide, biotite, (metamorphic?), epidote, apatite, and zircon
Quartz lithic sandstone	50	SP512/3	55	25	5	10	-	Minor iron oxide, muscovite, biotite, and epidote
Lithic sandstone	25	SP512/2	45	30	5	10	-	Iron oxide(5), epidote(3), muscovite(2), and minor biotite

(ii) It is overlain by Lower Carboniferous units; and

(iii) It contains Leptophloeum australe in the Emerald Sheet area (White, 1962), which is known from the Upper Devonian although it may range into Lower Carboniferous.

Table 2 summarizes the results of the examination of thin sections from the measured section shown in Figure 4. The quartz grains are commonly angular; a few are embayed. The feldspars are commonly fresh and consist of equal proportions of alkali feldspar and plagioclase. Epidote and chlorite are common alteration products, possibly diagenetic. The clots of biotite flakes in some of the rocks may be clastic or secondary diagenetic products.

The thickness of the Telemon Formation was estimated by Shell (SQD, 1952) to be 7000 feet. The basal conglomeratic beds are estimated to be about 2000 feet thick in the type area in the Nogoa Anticline, and only 50 feet thick in the Telemon Anticline. The upper multicoloured lutitic beds are about 5000 feet thick in the type area and 3000 feet thick in the Telemon Anticline; in the southwestern part of the anticline they are probably less than 1000 feet thick.

CARBONIFEROUS

Mount Hall Conglomerate

The Mount Hall Conglomerate (Hill, 1957) was originally named by Shell (SQD, 1952) after Mount Hall in the Telemon Anticline, which is the type locality. It crops out in the Telemon, Nogoa, and Vandyke Anticlines, and also in the Emerald Sheet area to the north. It forms prominent cuestas and strike ridges on the northwestern and eastern limbs of the Telemon Anticline. The outcrops are covered by scrub and timber which have a distinctive dark tone on the air-photographs.

The Mount Hall Conglomerate is an orthoquartzite conglomerate (Pettijohn, 1957) consisting dominantly of rounded pebbles of milky quartz, with a few pebbles of black and dark green chert, fine quartzite, indurated fine quartzose sediments, jasper, and perhaps fine-grained volcanics; some pockets of cobbles are present. The conglomerate is well sorted, and most of the pebbles are between 1 and 2 inches across. The pebbles are set in a coarse-grained matrix of quartz sandstone with a kaolinitic cement. Interbeds of kaolinitic quartz sandstone with scattered pebble layers are present. The conglomerate is commonly very coarsely cross-bedded. In the Telemon and Nogoa Anticlines conglomerate is predominant, but in the anticline immediately southeast of the Nogoa Anticline, where the formation is thickest, about half of it consists of feldspathic quartz sandstone.

The Mount Hall Conglomerate disconformably overlies the Telemon Formation and is conformably overlain by the Raymond Sandstone. The boundary with the Raymond Sandstone is transitional. The top of the Mount Hall Conglomerate is taken at the top of the highest conglomeratic sandstone or conglomerate. In the Nogoa Anticline and in the western part of the Telemon Anticline the formation is represented only by thin lenses of conglomerate. The conglomerate is an excellent marker because of its distinctive lithology, prominent outcrops, and distinctive pattern on the air-photographs. One mile southwest of Connemarra homestead, the northern end of the Nogoa Anticline is defined by a narrow ridge of Mount Hall Conglomerate, about 100 yards long.

The Mount Hall Conglomerate represents a change in provenance and environment of deposition from the Telemon Formation: it marks the beginning of a period of deposition of fluviatile quartz sand. The lithology of the pebbles suggests that much of the formation was derived from the Anakie Metamorphics to the north in the Emerald and Clermont Sheet areas. The conglomerate was probably initially deposited by streams as fans in shallow freshwater depressions, and reworked and redistributed by streams which altered course in response to slight epeirogenic movements. It is possibly related to uplift of the provenance area or to a marked change of climate from that in Telemon times. The disconformity with the Telemon Formation suggests epeirogenic uplift between the two formations.

The Mount Hall Conglomerate is lenticular: it is about 1500 feet thick a few miles west of Euneeke homestead; in the northeast limb of the Telemon Anticline it is about 1000 feet thick; and in the Emerald Sheet area it has a maximum thickness of 2600 feet (Veevers et al., 1964a).

The Mount Hall Conglomerate contains fossil plants which are probably Lower Carboniferous in age (SP41 and SP89/1, App. 3); it is separated from the Lower Carboniferous Ducabrook Formation only by the Raymond Sandstone, at the top of which there is probably a disconformity.

Raymond Sandstone

The Raymond Sandstone (Veevers et al., 1964a) was originally named the Flaggy Sandstone Group by Shell (SQD, 1952) and renamed the Raymond Flaggy Sandstone by Hill (1957). The type area is at the southern end of the Telemon Anticline around Raymond Creek.

The Raymond Sandstone crops out in the Telemon, Nogoa, and Vandyke Anticlines. It forms prominent strike ridges and cuestas, which have a distinctly lighter tone than the Mount Hall Conglomerate on the air-photographs. It crops out to the north in the Emerald Sheet area.

In the type area the Raymond Sandstone consists predominantly of medium-bedded flaggy fine and medium-grained micaceous quartz sandstone; it is commonly buff-brown and greenish brown, and in places creamy white. The sandstone contains carbonaceous fragments, commonly along bedding planes. The abundance of mica in the thin-bedded sandstone imparts a characteristic flaggy fissility. Some of the sandstone contains significant amounts of feldspar and lithic grains. Thin siltstone interbeds are present. The flaggy quartz sandstone is commonly cross-bedded in units 1 to 2 feet thick; the foreset beds are flaggy and gently dipping. Individual sandstone beds can be traced for several miles on the air-photographs.

Chert breccia, noted also by Shell (SQD, 1952), is present at the top of the formation at the southern end of the Telemon Anticline. The breccia consists of fractured angular to subrounded pebbles, up to 2 inches across, of milky quartz, chert, and perhaps volcanics, in an unsorted matrix with a cherty cement.

The Raymond Sandstone grades from the Mount Hall Conglomerate below, and where the Mount Hall Conglomerate is absent, it rests disconformably on the Telemon Formation. The chert breccia at the top of the Sandstone suggests a period of non-deposition, and there may be a local disconformity at the top.

The sediments were probably transported from the basin hinterland by mature streams and deposited in a shallow non-marine basin. The provenance was probably the same as the Mount Hall Conglomerate. Conditions in the basin were fairly stable, with gentle currents reworking and redistributing sand. The flaggy bedding is probably due to the settling out of flakes of mica during short intervals when sand was not being deposited.

The Raymond Sandstone is 1200 feet thick at the southern end of the Telemon Anticline, but only 100 feet thick where Mistake Creek intersects the east limb of the Telemon Anticline.

Section S2

3/5 mile W. of Echo Hills Homestead (Pl.6)

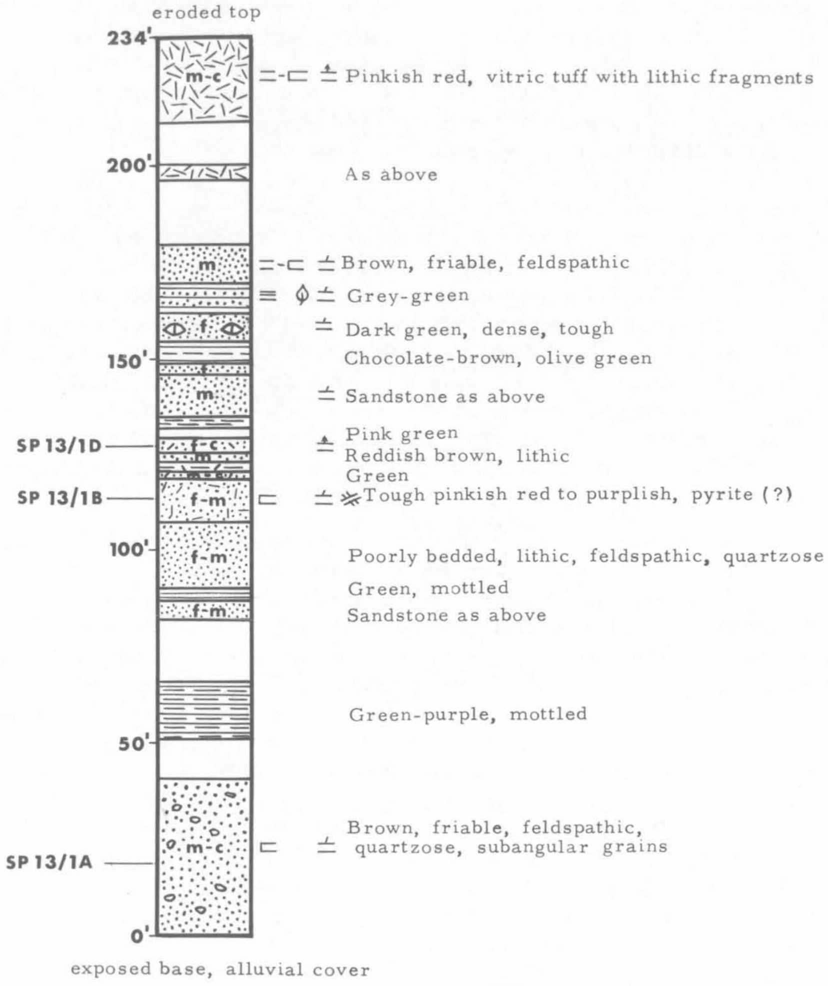

Figure 5

The Raymond Sandstone contains indeterminate plant remains. It is regarded as Lower Carboniferous as it is separated from the Lower Carboniferous Ducabrook Formation only by a local disconformity.

Ducabrook Formation

The Ducabrook Formation (Hill, 1957) was originally named the Ducabrook Series by Shell (SQD, 1952) after Ducabrook pastoral holding in the Emerald Sheet area.

The formation crops out extensively in the northwest quadrant of the Springsure Sheet area in the Nogoa, Telemon, Medway, and Vandyke Anticlines. It underlies fairly flat soil and scrub-covered country, with some low ridges in the Nogoa Anticline area. The country is more undulating between the Telemon and Medway Anticlines, north and east of Echo Hills homestead, where closely spaced groups of strike ridges and small scarps are separated by river flats. The formation generally has a dark tone on the air-photographs, in which the trend of the bedding is distinct; the pattern is similar to that of the upper part of the Telemon Formation.

The Ducabrook Formation is lithologically similar to the upper multicoloured beds of the Telemon Formation: it comprises a thinly interbedded sequence of arenites and lutites with much primary volcanic and reworked volcanic material. Shell (SQD, 1952), Veevers et al. (1964a), and the present survey have shown that it is difficult to subdivide the unit. Pallister (in Schneeberger, 1942), who mapped the Bogantungan-Zamia area of the Emerald Sheet area says: 'For local correlation, subdivisions were made of the Ducabrook Series .... based on the variable predominance of certain lithological types and no distinct boundary horizons can be traced, therefore the groups are not expected to be of wide application nor are their separate thicknesses closely comparable even within the limits of this area'. Pallister's remarks apply equally well to the Springsure area, where vertical and lateral changes, both local and regional, are abrupt.

The best exposures are on the west flank of the Telemon Anticline. The sequence contains pebble conglomerate and conglomeratic sandstone near the base and the top; the conglomeratic beds consist of rounded pebbles of quartz and chert, ranging from 1/4 to 3 inches across, set in a matrix of feldspathic quartz sand. The sandstone beds are deep purplish brown, khaki-brown, and green; they contain varying proportions of quartz, volcanics, low-grade metamorphics, and feldspar, set in a matrix which is commonly tuffaceous. Some of the tough green sandstone is calcareous and has a fontainebleau texture. Mud clasts and mud flakes, up to several inches across, are present at the base of some of the sandstone beds. Other sandstone beds contain dark bands composed of secondary hematite, limonite, and pyrite. The sandstone is commonly cross-bedded and festoon-bedded, with current striations and sole marks on the bedding planes. The mudstone and siltstone are commonly dense tuffaceous and cherty rocks. The mudstone is reddish purple, olive-green, and khaki; it is generally massive, and rarely shaly. Tough pinkish red beds of rhyolitic vitric tuff showing crude graded bedding are characteristic of the upper part of the formation.

The measured section in Figure 5 illustrates the lithology of the upper part of the Ducabrook Formation. Specimen SP13/1A is a feldspathic lithic quartz sandstone with some mica. The lithic grains consist predominantly of metasediments, but some grains of tuff are also present. The subordinate matrix is probably volcanic ash. Specimen SP13/1B is a vitric tuff consisting of glass shards in a reddish brown volcanic dust. Specimen SP13/1D is a crystal-lithic tuff. Stratigraphic drill holes BMR Springsure 10 and 11 penetrated fresh mudstone and siltstone in the upper part of the Ducabrook Formation (Arman, 1965a).

Silty limestone with layers of oolites is present; individual oolites are commonly less than an eighth of an inch in diameter. Several lenses of algal(?) limestone were found; individual colonies are commonly cylindrical, and about an inch in diameter and several inches long.

The detailed lithology of the Ducabrook Formation is given in Veevers, Mollan, Olgers, & Kirkegaard (1962, app. 1) and Schneeberger (1942, app. 4).

Numerous small folds, with amplitudes of 2 feet, occur in sandstone at the top of the Telemon Anticline. The folds have sharp acute crests, and are fractured along vertical axial planes. They have no common orientation, and are found only in the highest exposed beds. They may have been formed during the folding of jointed sandstone, the compressional forces within the sandstone being released at the joints by the formation of the folds. Alternatively, they are permafrost structures, formed in an exposed sandstone bed, possibly at the onset of the glacial Joe Joe Formation period. The size and form of the folds are similar to permafrost structures in Wales (Bradshaw & Ingle-Smith, 1963).

The Ducabrook Formation rests probably disconformably on the Raymond Sandstone at the southern end of the Telemon Anticline; elsewhere it is probably conformable. It is unconformably overlain by the Joe Joe Formation.

The formation was deposited in a shallow non-marine basin which was probably subjected to epeirogenic movements. The mud clasts and mud flakes at the base of sandstone beds were probably formed during periods of non-deposition and desiccation followed by renewed inundation. The conglomerate and festoon-bedded conglomeratic sandstone are probably fluviatile gravels. The presence of algae, red-beds, oolites, fish, and small pelecypods attest to abrupt changes in depositional environment; the rapid changes in lithology along the strike are the result of rapid changes of environment within the basin. Volcanic activity on the margins of the basin persisted throughout the deposition of the formation, and increased in intensity in the late stages.

Shell (SQD, 1952) report that the Ducabrook Formation ranges from 5800 to 8500 feet in thickness. In the east limb of the Telemon Anticline it is estimated to be about 5000 feet thick.

In the Emerald Sheet area, the Ducabrook Formation contains Lower Carboniferous fossil fish remains (Jack & Etheridge, 1892; SQD, 1952), and the Lower Carboniferous plant fossil Lepidodendron veltheimianum (White, 1962). The following fossils were found during the present survey: (i) Several fish scales at locality SP32, a mile southeast of Rooken Glen homestead; (ii) Small pelecypods, about 1 inch long, at localities SP361/6 and SP358/4, about 5 miles west-southwest of Tresswell homestead; (iii) Casts and impressions of lepidodendroid stems at numerous localities (see app. 3); (iv) Megaspores(?) at locality SP352/2, about a mile northwest of Tresswell homestead; (v) Several lenses of algal limestone 4 miles north-northeast of Riverside homestead (SP361/4) and 6 miles east-northeast of Echo Hills homestead (SP773).

CARBONIFEROUS-PERMIAN(?)

Joe Joe Formation

The Joe Joe Formation was originally named the Joe Joe Creek Series by Shell (SQD, 1952) and amended to Joe Joe Creek Formation by Hill (1957); it is now abbreviated to Joe Joe Formation. The name is derived from Joe Joe Creek in the northwest part of the Springsure Sheet area; the type area is in the vicinity of the creek; a type section has not been proposed.

The formation crops out in a belt extending from the southern part of the Nogoa Anticline to the western boundary of the Sheet area, with lobes extending northwards in synclines. The upper part of the unit is fairly well exposed, but much of the lower part is concealed by gravel. In the conglomeratic lower part of the formation, which forms low rounded hills with a dendritic drainage pattern, the bedding and structural trends cannot be distinguished on the air-photographs. The bedding is more pronounced in the upper part, and resistant beds form low cuestas and several prominent mesas and ridges.

The lower part of the Joe Joe Formation consists of tillitic conglomerate, conglomeratic mudstone, and quartz lithic sandstone (Pl. 1). The tillitic conglomerate is mainly a cobble conglomerate with a few boulders. Pebble and cobble conglomerates tend to alternate. At least 50 percent of the pebbles, cobbles, and boulders consist of quartzite and fine-grained quartzitic sediments, commonly veined with quartz; the rest consists of granitic rocks, volcanics (mainly porphyritic acid types), milky quartz, slate, phyllite, schist, soft lutite, and coralline limestone (see app. 4). Boulders of fossiliferous limestone, up to 3 feet across, are common at locality SP600. The boulders are subangular and commonly have striated facets (Pl. 2, fig. 2); the cobbles and pebbles are commonly subrounded to rounded with poorly preserved striated facets.

The tillitic conglomeratic mudstone is unsorted and poorly bedded. At least 80 percent of the rock consists of light green sandy mudstone; it is commonly slightly calcareous and contains scattered pebbles, cobbles, and boulders similar to those in the tillitic conglomerate. Most of the clasts are rounded, but some are angular or tabular, and a few are faceted and striated. Erratics of granite and porphyry, up to 6 feet across, are commonly found close to outcrops of conglomeratic mudstone. The tops of conglomeratic mudstone beds are often scoured, and where they rest on sandstone scour marks are common in the top of the sandstone. The conglomerate is similar to the tillite described in Pettijohn (1957), except for the high proportion of rounded rather than angular cobbles and boulders (Pl. 1).

The sandstone is a quartz lithic variety. It is brown, friable, fine to medium-grained, and poorly bedded to massive. Lithic grains predominate; they comprise fine-grained volcanics, tuff, schist, and metasediments. The quartz grains are strained and cracked. About 10 percent of the grains consist of perthite and oligoclase. Most of the intergranular spaces are void, and the sandstone is porous at the surface; the grains have a film of chloritic material which forms a weak cement. Slump rolls were observed in some of the sandstone beds.

The upper part of the formation, which is illustrated in Figure 6, consists essentially of very fine-grained sandstone, siltstone, fine to medium-grained quartz lithic sandstone, carbonaceous shale with thin coaly bands, fine-grained grey limestone, and tuff. Fine-grained sandstone and siltstone are predominant, and most of the angular and subangular grains of quartz are about 0.05 mm in diameter. The grains are set in a chloritic matrix. The sediments are thinly bedded to laminated, finely festoon-bedded, and show interference ripple marks. The siltstone commonly contains laminae and thin beds of greenish grey clay-shale, mostly at irregular intervals; the finely interbedded siltstone and clay-shale are similar to varves (Pl. 2, fig. 1). The bedding planes in the siltstone commonly show two types of tracks (Pl. 3), probably of arthropods.

The sandstone is similar to that in the lower part of the formation; it is calcareous in part and contains rare pebbles. Thin beds and thin discoidal concretions of limestone, up to 3 feet across, occur in the siltstone. The thin limestone beds are current ripple-marked in places. Beds of tough light greenish grey siltstone packed with plant fragments are common. A bed of creamy to pale pink vitric tuff, 20 feet thick, occurs near the middle of the Joe Joe Formation (Fig. 6); in places it contains thin interbeds of indurated

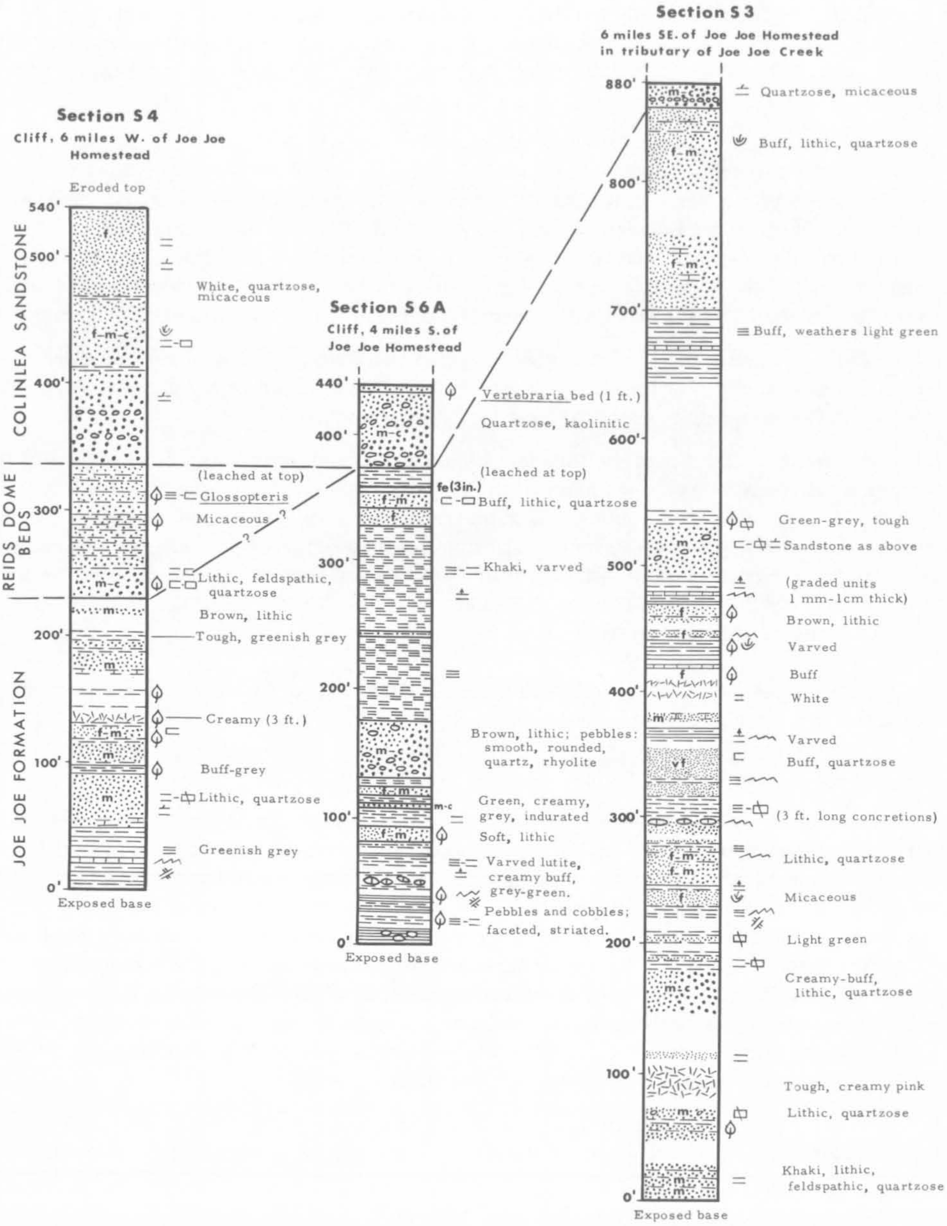
Section S4
Cliff, 6 miles W. of Joe Joe Homestead
Eroded top
540'
500'
400'
300'
200'
100'
0'
Exposed base
COLINLEA SANDSTONE
REIDS DOME BEDS
JOE JOE FORMATION
f
f-m-c
m-c
m
f-m
White, quartzose, micaceous
(leached at top)
Glossopteris
Micaceous
?
Lithic, feldspathic, quartzose
Brown, lithic
Tough, greenish grey
Creamy (3 ft.)
Buff-grey
Lithic, quartzose
Greenish grey
Section S6A
Cliff, 4 miles S. of Joe Joe Homestead
440'
400'
300'
200'
100'
0'
Exposed base
Vertebraria bed (1 ft.)
Quartzose, kaolinitic
(leached at top)
fe(3in.)
Buff, lithic, quartzose
Khaki, varved
Brown, lithic; pebbles: smooth, rounded, quartz, rhyolite
Green, creamy, grey, indurated
Soft, lithic
Varved lutite, creamy buff, grey-green.
Pebbles and cobbles; faceted, striated.
Section S3
6 miles SE. of Joe Joe Homestead in tributary of Joe Joe Creek
880'
800'
700'
600'
500'
400'
300'
200'
100'
0'
Exposed base
vf
Quartzose, micaceous
Buff, lithic, quartzose
Buff, weathers light green
Green-grey, tough
Sandstone as above
(graded units 1 mm-1cm thick)
Brown, lithic
Varved
Buff
White
Varved
Buff, quartzose
(3 ft. long concretions)
Lithic, quartzose
Micaceous
Light green
Creamy-buff, lithic, quartzose
Tough, creamy pink
Lithic, quartzose
Khaki, lithic, feldspathic, quartzose

Figure 6

blue-grey mudstone with well preserved plant remains, especially near Joe Joe homestead (locality SP606, see App. 3). Thinner beds of tuff also occur higher in the sequence. Bastian (in prep. b) has described specimens from the Joe Joe Formation.

Shell geologists (SQD, 1952) state that the Joe Joe Formation is 2500 feet thick, and in the type area we estimate from the regional dip and air-photographs that it is 2000 feet thick. The formation, and particularly the upper non-conglomeratic part, thins to the east and probably thickens to the west of the type area. To the east of the Nogoa Anticline there are only isolated outcrops of the conglomeratic lower part; the upper part is absent.

The Ducabrook Formation was folded before the Joe Joe Formation was laid down, the unconformity was observed in the southern nose of the Medway Anticline. In the southern part of the Nogoa Anticline (Pl. 6), conglomerate of the Joe Joe Formation overlaps the Ducabrook Formation and Raymond Sandstone, and rests on the Telemon Formation; the contacts with the underlying formations have not been observed. At the southern end of the Mistake Syncline, and in the syncline immediately west of the Telemon Anticline, the Joe Joe Formation is apparently conformable with the Ducabrook Formation.

Similarly, the Colinlea Sandstone rests unconformably on the Joe Joe Formation in anticlines and disconformably in synclines. The thinning of the Joe Joe Formation below the Colinlea Sandstone to the east is due to erosion.

The white fine-grained sediments which Shell considered to be the basal part of the Colinlea Sandstone are now considered to be a leached zone at the top of the Joe Joe Formation, because they contain the same flora (locality SP301, App. 3) as the Joe Joe Formation. The leached zone, which indicates a period of non-deposition, is underlain by a ferruginous ripple-marked siltstone which extends for several square miles in the area where sections S6A and S6B were measured (Fig. 6). The ferruginization represents a period of non-deposition and desiccation.

A few miles south of Mount Paddy and 2 miles west of Connemarra homestead the Joe Joe Formation is disconformably overlain by a thin representative of the Reids Dome Beds, containing Glossopteris (see Fig. 6). Two miles southeast of Nandowrie Needle the unit appears to be unconformable on the Joe Joe Formation.

The Joe Joe Formation was deposited on an uneven terrain formed by folds in the Drummond Basin sequence, mainly in glacial lakes from streams fed by glaciers. The tillitic conglomerate and conglomeratic mudstone represent fluvially reworked moraines and boulder clay; some beds probably represent boulder clay which has not been reworked, and it can be inferred that the ice sheets advanced and retreated several times. The deposition of much of the upper part of the formation followed the retreat of the ice and the formation of lakes fed by glacial meltwater, in which varved lutite was deposited. The presence of mud cracks in the sediments suggests that the lakes dried up periodically. Bottom life abounded in the lakes, which were subject to currents (Pl. 3). The presence of beds of tuff indicates contemporaneous vulcanicity.

Compactional and depositional dips in the glacigene sediments tend to obscure the major unconformity at the base of the Joe Joe Formation in areas such as the Mistake Syncline.

Contorted mudstone beds with dispersed faceted cobbles were observed about 3½ miles southwest of Echo Hills homestead; tongues of mudstone, about 5 feet high, project into overlying beds. They appear to be similar to permafrost structures studied by Bradshaw & Ingle-Smith (1963).

Many of the pebbles, cobbles, and boulders can be traced to older units exposed to the west and north in the Springsure, Emerald, and Clermont Sheet Areas. They include:

lower Middle Devonian coralline limestone (App. 4) found only in the Dunstable Volcanics; slate, phyllite, schist, milky quartz, and gneiss(?) similar to the Anakie Metamorphics, which crop out extensively in the Clermont and Emerald Sheet areas and in the Telemon Anticline; soft lutite similar to that in the Ducabrook and Telemon Formation; porphyritic volcanics similar to those in the Dunstable and Silver Hills Volcanics; granite similar to the Retreat Granite in the Emerald Sheet area, and the granite in the Telemon Anticline; and quartzite and indurated quartz-veined quartzose sediments which were possibly derived from an earlier siliceous duricrust.

The formation contains well preserved plant remains, notably the fern Cardiopteris polymorpha, which, according to White, is Carboniferous (App. 3). Glossopteris is apparently absent. Spores indicate that the formation is Upper Carboniferous and that the uppermost part in the extreme west is probably Permian (Evans, 1964a); the absence of the younger sequence is probably related to erosion and overlap at the base of the Colinlea Sandstone. Druce (App. 5) has identified lower or upper Middle Devonian conodonts, crinoid ossicles, and a gastropod in specimens collected by J.E. Heppert and A.W. Lindner of Amoseas Petroleum Ltd. The Devonian conodonts are probably from erratics derived from the same unit as the erratics containing Devonian corals (App. 4).

PERMIAN

The thick Permian sequence is well exposed in the Springsure, Serocold, and Consuelo Anticlines. The sequence can be readily subdivided because it consists of alternating sandstone and lutite units. Some formations contain marine macrofossils which have been regarded as standards for correlation throughout the Bowen Basin. Recent work, however, has shown that the sequence in the Springsure Sheet area is not typical of the basin as a whole, and that some parts of the sequence contain fewer fossiliferous horizons than the same parts of the sequence elsewhere (see App. 1).

In this Report the stratigraphy of the Permian sediments has been revised in the light of our work in the Springsure Sheet area, and the revised concept of the general stratigraphy and structure of the Bowen Basin which has evolved in the past six years. We gratefully acknowledge fruitful discussion on problems of stratigraphic revision with many geologists.

Revised Permian Stratigraphy

Where possible the original definitions and usages of formations have been retained. Several of the formations were only loosely defined by earlier workers, and later workers applied these loose definitions to different parts of the sequence. These formations are more precisely defined in this Report and type sections are proposed for some. The stratigraphy is summarized in Table 3.

(1) The name Reids Dome Beds is introduced to cover the beds below the Cattle Creek Formation in the AOE No. 1 (Reids Dome) well, which were originally named the 'undivided freshwater beds' and 'lower shales and mudstones' by Webb (1956). A thin representative of the unit crops out between the Joe Joe Formation and the Colinlea Sandstone in the northwest. The Orion Formation (Webb, 1956), which crops out only in the Springsure Anticline, is a formation at the top of the Reids Dome Beds.

(2) The Dilly beds of Reid (1930) are subdivided into the Orion Formation (Webb, 1956) and Stanleigh Formation (Phillips, in Hill & Denmead, 1960).

(3) The Catherine Sandstone is used as originally defined by Reid (1930). The Catherine Sandstone of Hill (1957) is subdivided into the Catherine Sandstone and the Peawaddy Formation (Mollan, Kirkegaard, Exon, & Dickins, 1964); the latter contains coquinitic lenses of the Mantuan Productus Bed at the top (outcrops of the Mantuan Productus Bed are shown in Pls 6, 7A, 7B).

(4) The Colinlea Formation of Hill (1957) is referred to three units: the Reids Dome Beds, Colinlea Sandstone (Mollan, Kirkegaard, Exon, & Dickins, 1964), and Peawaddy Formation. The name Colinlea is retained for the sandstone which alone crops out at the type locality.

(5) The Bandanna Formation of Hill (1957) is subdivided; the lower part is the Black Alley Shale, a newly named formation defined here, and the upper part is the Blackwater Group (Malone, Olgers, & Kirkegaard, 1969).

(6) The Cheshire Formation of Hill (1957) is abandoned, as it was found to include the Black Alley Shale, Blackwater Group, and Rewan Formation.

(7) The Aldebaran Sandstone is subdivided into three members not formally named (a lower sandstone member, a middle conglomerate member, and an upper transition member), which are shown in Plates 7A and 7B. Since our work and maps were completed, Power (1966) has named the transition member the Freitag Formation.

Stratigraphic Relationships in the Permian

(1) The Cattle Creek Formation is regarded as equivalent to the interval from the base of the Stanleigh Formation to the top of the Sirius Formation.

(2) The Colinlea Sandstone is probably equivalent to the interval from the base of the middle conglomerate member of the Aldebaran Sandstone ($P11_2$ in Pls 7A, 7B) to the top of the Catherine Sandstone. The Ingelara Formation wedges out to the west of the Springsure Anticline.

(3) The Marine Permian units of the Denison Trough are related to the three subgroups of the Back Creek Group, Units A, B, and C, and Faunas I, II, III, and IV of Dickins, Malone, & Jensen (1964), as follows:

BACK CREEK GROUP	Blenheim Subgroup *(Unit C, Fauna IV)	Black Alley Shale (Mantuan *Productus* Bed) Peawaddy Formation
	Gebbie Subgroup (Unit B, Fauna III)	Catherine Sandstone Ingelara Formation Aldebaran Sandstone
	Tiverton Subgroup (Unit A, Faunas II & I?)	Cattle Creek Formation

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* For Tiverton, Gebbie, and Blenheim Subgroups see Malone, Olgers, & Kirkegaard (1969).

TABLE 3: RELATIONSHIPS OF PERMIAN SUBDIVISIONS PROPOSED BY DIFFERENT AUTHORS

<table>
<tr><th></th><th colspan="3">This Report (Also Mollon, in press)</th><th colspan="3">Reid (1930)(1)</th><th colspan="3">Hill (1957)</th><th colspan="2">Power (1966)</th><th colspan="4">Other names used in Permian stratigraphy</th></tr>
<tr><th></th><th>Serocold Anticline</th><th>Springsure Anticline</th><th>Springsure Shelf</th><th colspan="2">Serocold Anticline</th><th>Springsure Anticline</th><th>Serocold Anticline</th><th>Springsure Anticline</th><th>Springsure Shelf</th><th colspan="2">Springsure Anticline</th><th colspan="2">Laing (1961)(2)</th><th colspan="2"></th></tr>
<tr><td rowspan="4">Upper Permian</td><td colspan="3">Blackwater Group*
(Malone, Olgers & Kirkegaard, in press)</td><td colspan="3">Upper Bowen
? ? ? ? ?</td><td rowspan="2">Bandanna Formation *</td><td>'Upper part'</td><td rowspan="2">Cheshire Formation*
(includes Triassic Rewan Formation)</td><td colspan="2"></td><td>Southern part of Serocold Anticline</td><td>Reids Dome part of Serocold Anticline</td><td></td><td rowspan="13"></td></tr>
<tr><td colspan="3">Black Alley Shale*</td><td colspan="3" rowspan="3">Middle Bowen Marine Series*</td><td>'Lower part'</td><td colspan="2">Black Alley Shale</td><td>Dry Creek Shale(3)</td><td></td><td rowspan="4">Consuelo Stage *
(including Consuelo Sandstone * Catherine Sandstone of this Report)
(Reeves, 1947)</td></tr>
<tr><td colspan="3" rowspan="2">(Mantuan Productus Bed)
Peawaddy Formation*
(Mollan, Kirkegaard, Exon & Dickins, 1964)</td><td colspan="2" rowspan="3">Mantuan Productus Bed *
Catherine Sandstone</td><td rowspan="7">Colinlea Formation *</td><td colspan="2" rowspan="2">Peawaddy Formation</td><td>Early Storms Sandstone(4)</td><td rowspan="2">Dry Creek Shale *</td></tr>
<tr><td rowspan="2"></td></tr>
<tr><td rowspan="10">Lower Permian</td><td colspan="2">Catherine Sandstone</td><td rowspan="4">Colinlea Sandstone</td><td rowspan="7">Lower Bowen*
?</td><td>Catherine Sandstone *</td><td rowspan="5">Serocold Sandstone *</td><td colspan="2">Catherine Sandstone</td><td>Early Storms Sandstone *</td></tr>
<tr><td colspan="2">Ingelara Formation*
(Raggatt & Fletcher, 1937)</td><td>Coral Stage *</td><td colspan="2" rowspan="2">Ingelara Formation</td><td colspan="2">Ingelara Formation</td><td colspan="2" rowspan="9"></td><td rowspan="7"></td></tr>
<tr><td rowspan="3">Aldebaran Sandstone</td><td>upper transition member</td><td rowspan="3">Aldebaran Sandstone *</td><td colspan="2">Freitag Formation *</td></tr>
<tr><td>middle conglomerate member</td><td colspan="2" rowspan="2">Aldebaran Sandstone</td><td colspan="2" rowspan="2">Aldebaran Sandstone</td></tr>
<tr><td>lower sandstone member</td><td rowspan="4">Hiatus</td></tr>
<tr><td rowspan="3">Cattle Creek Formation</td><td>Sirius Formation*
(Webb, 1956)</td><td>Gypseous Marine Stage *</td><td rowspan="2">Dilly Beds *</td><td colspan="2">Cattle Creek Formation *</td><td rowspan="5">? ?</td><td rowspan="3">Cattle Creek Formation</td><td>Sirius Mudstone Member</td></tr>
<tr><td>Staircase Sandstone</td><td>Staircase Sandstone *</td><td rowspan="4"></td><td>Staircase Sandstone</td><td>Staircase Sandstone Member</td></tr>
<tr><td>Stanleigh Formation*
(Phillips in Hill & Denmead, 1960)</td><td colspan="3" rowspan="3">Base of outcrop</td><td rowspan="2">Dilly Beds</td><td>Riverstone Sandstone Member *
Middle Mudstone Member
Lower Mudstone Member</td></tr>
<tr><td></td><td>Orion Formation
(Webb, 1956)</td><td></td><td colspan="2">Orion Formation</td><td rowspan="2">'Undivided fresh-water beds' and 'Lower shales and mudstones'
(Webb, 1956)</td></tr>
<tr><td colspan="3">Reids Dome Beds*</td><td></td><td colspan="2">(Reids Dome Beds)</td><td>Rolleston Conglomerate *
Cundill, Meyers & Associates 1965.</td></tr>
</table>

* First published reference to name

1. Reid mapped Serocold Sandstone and Dilly Beds above the Catherine Sandstone in the East flank of the Springsure Anticline because he did not recognize the Consuelo Anticline, and postulated a non-existent major Consuelo Fault (down on south) between the Springsure and Serocold Anticlines.
2. The ambiguity arose essentially because the wedge-out of the Catherine Sandstone at the southern end of Reids Dome was not recognized.
3. First published Allen (1962)
4. First published Sanker (1962)

Reids Dome Beds (New name)

The name Reids Dome Beds is introduced in place of the 'undivided freshwater beds' and 'the lower shales and mudstones' of Webb (1956). Webb's informal names apply only to the subsurface Lower Permian units in AOE No. 1 (Reids Dome), and were thought by Webb to be separated by an unconformity. The Reids Dome Beds are regarded as having group status; the Orion Formation, which represents the uppermost few hundred feet of the unit, is exposed only in the Springsure Anticline. Thin representatives of the Reids Dome Beds crop out in the west.

The Reids Dome Beds have been encountered in numerous oil exploration wells (Pls 8A,8B). The group comprises interbedded arenite, lutite, and coal. In AFO Rolleston No. 1 and AAO Glentulloch No. 1 the beds contain thick conglomerate.

Thin representatives of the Reids Dome Beds crop out in three areas in the west: west of Connemarra homestead, northwest of Hillview homestead, and west of Joe Joe homestead. The outcrops are in cliffs immediately below the Colinlea Sandstone. In the first two localities the beds consist of about 15 feet of sandstone and shale, and in the third locality 120 feet of sandstone and siltstone were measured (Fig. 6). Thin coal seams are present.

The Reids Dome Beds are 7365 feet thick in AOE No. 1 (Reids Dome) well, in which the base was not penetrated. One thousand to 3000 feet of the Reids Dome Beds were penetrated in many other wells in the Denison Trough (Pls 8A, 8B). The beds thin out rapidly to the east and west of the trough; in AFO Purbrook No. 1 and AAO Glentulloch No. 1 they rest unconformably on the Timbury Hills Formation, which is probably Devonian. The andesite in the bottom of SQD No. 1 (Morella) is possibly older than the Reids Dome Beds. The volcanics in the bottom of Marathon-Continental Glenhaughton No. 1 are possibly related to the Camboon Andesite, a Lower Permian formation cropping out to the east in the Mundubbera Sheet area. The Camboon Andesite is probably equivalent to the Reids Dome Beds (Pl. 8B).

In the Springsure Shelf, the thin representatives of the Reids Dome Beds rest unconformably on the Ducabrook Formation near Connemarra homestead, unconformably on the Joe Joe Formation near Hillview homestead, and disconformably on the Joe Joe Formation west of Joe Joe homestead. The beds are unconformably overlain by the Colinlea Sandstone in the first two areas and disconformably overlain by the Colinlea Sandstone west of Joe Joe homestead.

The Reids Dome Beds were deposited mainly in the rapidly subsiding Denison Trough; the north-south elongation of the trough and the amount of downwarping are apparent from the variation in thickness of the unit (Pls 8A, 8B). The lack of marine fossils, and the wide distribution of coal in bores, and of plant beds and rootlets in outcrop, suggest a shallow freshwater swampy environment. Recurrent movements in the trough controlled the depth of water. The presence of sand in the later stages of deposition coincides with the transition to the marine environment of the Stanleigh and Cattle Creek Formations.

The Reids Dome Beds contain abundant plant remains, including several species of Glossopteris (App. 3), which suggest a Lower Permian age. Evans (pers. comm.) has also recorded Lower Permian spores.

Orion Formation

The name Orion Shale was used by Patterson (1955) and first published by Webb (1956) for about 200 feet of interbedded sandstone and carbonaceous shale exposed near the head of Orion Creek, which is here designated as the type area (Fig. 7). The formation is equivalent to the uppermost 300 feet of the Reids Dome Beds.

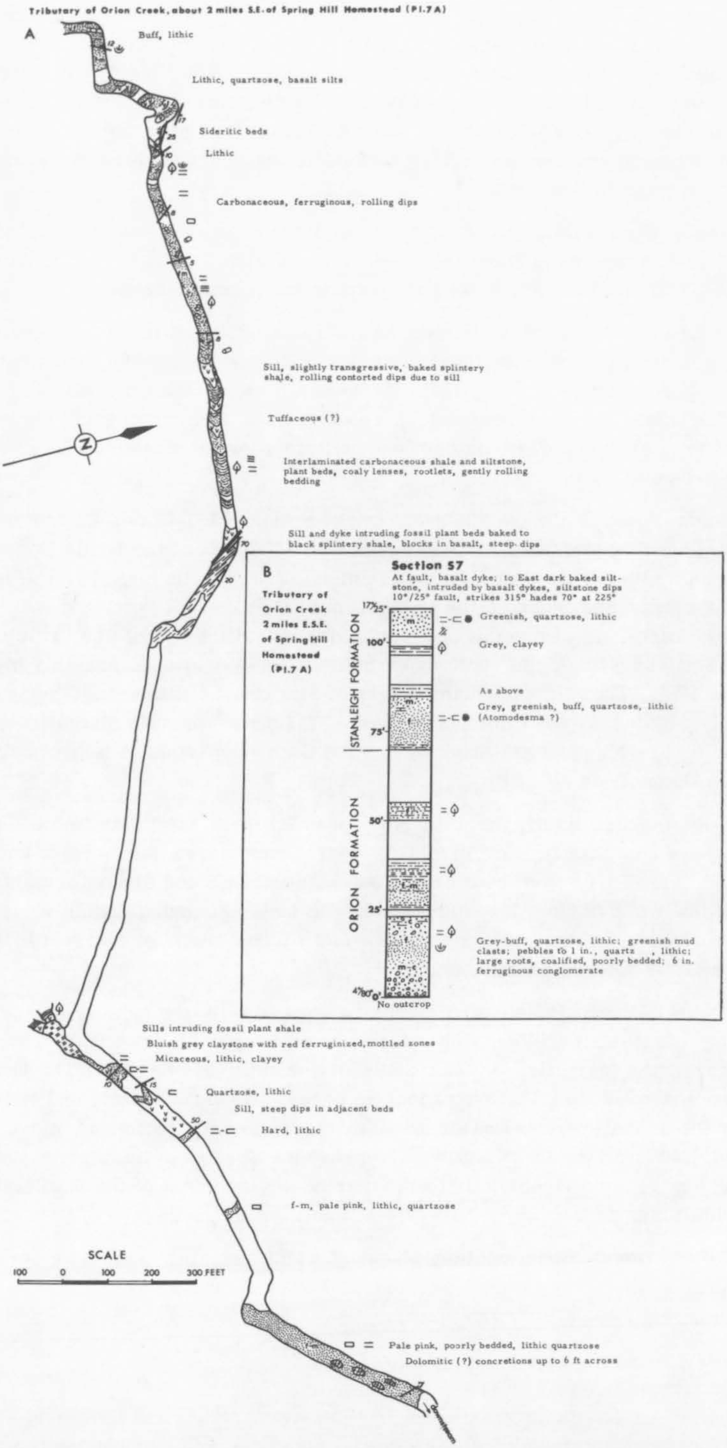
Tributary of Orion Creek, about 2 miles S.E. of Spring Hill Homestead (Pl.7 A)
A
Buff, lithic
Lithic, quartzose, basalt silts
Sideritic beds
Lithic
Carbonaceous, ferruginous, rolling dips
Sill, slightly transgressive, baked splintery shale, rolling contorted dips due to sill
Tuffaceous (?)
Interlaminated carbonaceous shale and siltstone, plant beds, coaly lenses, rootlets, gently rolling bedding
Sill and dyke intruding fossil plant beds baked to black splintery shale, blocks in basalt, steep dips
B
Tributary of Orion Creek 2 miles E.S.E. of Spring Hill Homestead (Pl.7 A)
Section 57
At fault, basalt dyke; to East dark baked siltstone, intruded by basalt dykes, siltstone dips 10°/25° fault, strikes 315° hades 70° at 225°
STANLEIGH FORMATION
ORION FORMATION
100'
75'
50'
25'
0'
Greenish, quartzose, lithic
Grey, clayey
As above
Grey, greenish, buff, quartzose, lithic (Atomodesma ?)
Grey-buff, quartzose, lithic; greenish mud clasts; pebbles to 1 in., quartz , lithic; large roots, coalified, poorly bedded; 6 in. ferruginous conglomerate
No outcrop
Sills intruding fossil plant shale
Bluish grey claystone with red ferruginized, mottled zones
Micaceous, lithic, clayey
Quartzose, lithic
Sill, steep dips in adjacent beds
Hard, lithic
f-m, pale pink, lithic, quartzose
SCALE
100 0 100 200 300 FEET
Pale pink, poorly bedded, lithic quartzose
Dolomitic (?) concretions up to 6 ft across

Figure 7

The Orion Formation crops out only within the Springsure Sheet, in two areas along the axis of the Springsure Anticline, one near the head of Orion Creek and the other 6 miles north of Springsure near the disused Dilly homestead: the area in between is obscured by Tertiary basalt. It is exposed only in creeks; elsewhere, it is overlain by flat soils. The trend of the bedding is faintly visible on the air-photographs in the Orion Creek area.

The Orion Formation comprises granular lithic quartz sandstone interbedded with siltstone and shale. The sandstone contains scattered pebbles, and the siltstone and shale contain abundant plant remains. The lithology near the head of Orion Creek is illustrated in Figure 7, and that in Springsure Creek is similar. The section in the unnamed creek shown in Figure 7 has not been measured accurately because of the rolling bedding and faulting due to the intrusion of numerous Tertiary basaltic dykes and sills. The shaly beds, some of which consist of layers of fossil leaves, are black and splintery adjacent to the Tertiary dykes and sills.

The formation contains coalified rootlets and grades up into the Stanleigh Formation, which contains marine macrofossils. Similar rock types occur in both formations (S7, Fig. 7). Patterson (1955) and Phillips (1959) postulated the presence of an unconformity between the two. We believe that the contortion of the bedding by faults and dykes and sills near the top of the Orion Formation and in the basal part of the Stanleigh Formation (Fig 7; Pl. 9A) misled Patterson and Phillips into describing the relationship as unconformable. Webb (1956) accepted the presence of an unconformity at the top of the Orion Formation and correlated it with his 'lower shales and mudstone' in AOE No. 1 (Reids Dome) because he considered the 'lower shales and mudstones' were unconformably overlain by the 'undivided freshwater beds'. We believe that the Orion Formation represents the top of the Reids Dome Beds, which grades into the marine Cattle Creek Formation; the transition is similar to the gradation between the Orion and Stanleigh Formations.

The maximum exposed thickness is probably about 300 feet, in the Orion Creek area. About 200 feet are exposed in the creek shown in Figure 7.

The Orion Formation contains an abundant Glossopteris flora of Lower Permian age (App. 3).

Cattle Creek Formation

The Cattle Creek Formation (Hill, 1957) was originally named the Cattle Creek Series by Shell geologists (SQD, 1952) after Cattle Creek, a tributary of Consuelo Creek in Reids Dome. An interval of 300 feet of nearly continuous exposure in Cattle Creek (S13, Pl. 9A) in the west limb of Reids Dome is proposed as the type section. The term Cattle Creek Shale was used by Phillips (in Hill & Denmead, 1960), but Cattle Creek Formation is preferred because the unit is not dominantly shaly. The formation crops out only along the axis of Reids Dome, and occupies an elongated depression, 10 miles long by 2 miles wide, surrounded by cliffs of Aldebaran Sandstone. The sandstone beds form low hills, but the formation generally underlies flat country with an even cover of timber. Most of the formation is covered by soil and scree. Faint bedding trends can be distinguished on the air-photographs in places.

In the type section, the Cattle Creek Formation consists predominantly of conglomeratic silty sandstone with thin interbeds of limestone and calcareous sandstone. The silty sandstone is dark grey, poorly sorted, and poorly bedded; it contains mica, carbonaceous material, and lenses and bands of gypsum along the bedding planes; jarosite is generally associated with the gypsum. Pebbles, cobbles, and boulders of quartz, quartz-veined metagreywacke, slate, phyllite, and porphyritic volcanics occur throughout the section. Boulders up to 5 feet across are present (Pl. 4, fig. 1), but most of them are much smaller. The pebbles and cobbles are smooth and rounded, but the boulders are mostly angular. Marine fossils occur throughout the sequence, and several bands and lenses of coquinite are present.

Lithic quartz sandstone occurs in beds up to 30 feet thick. The sandstone consists mainly of quartz grains and subordinate lithic grains, set in an argillaceous (hydromica) matrix. Slumped sandstone beds were observed.

A 10-foot bed of limestone, the '_Eurydesma_ Limestone' (Reid, 1930; Webb, 1956), occurs near the exposed base of the formation. At locality SP732 (Pl. 7B) it consists of 8 feet of bryozoan limestone with some shells, and 2 feet of coquinite at the top. The '_Eurydesma_ Limestone' was found at several localities near the culmination of Reids Dome.

The base of the formation is not exposed. In AOE Nos 1 and 2 (Reids Dome), it is apparently transitional with the Reids Dome Beds (Pl. 8A).

The Cattle Creek Formation is probably equivalent to the conformable Stanleigh-Staircase-Sirius sequence in the Springsure Anticline. This correlation was initially suggested by Patterson (1955); the sandstone in the AOE (Reids Dome) wells is probably a thin representative of the Staircase Sandstone. The lithology of the Cattle Creek Formation is similar to that of the Stanleigh and Sirius Formations, and Power (1966) has proposed a new nomenclature for the interval in the Springsure Anticline: the use of Cattle Creek Formation with three mudstone members separated by the Riverstone Member (new name proposed by Power) and Staircase Sandstone Member; he suggests that the use of the name Stanleigh Formation be discontinued (see Table 3). Mollan et al. (1964) suggested that the Cattle Creek Formation was equivalent to the Stanleigh Formation, but this is not supported by recent mapping and petrological work. The correlation now accepted implies that the '_Eurydesma_ Limestone' of the Stanleigh Formation and the Cattle Creek Formation are not equivalents.

The Cattle Creek Formation is predominantly marine, and the presence of gypsum suggests that it was deposited partly in a restricted basin. The sediments are generally poorly sorted, which suggests rapid deposition with little reworking. The '_Eurydesma_ Limestone' indicates a period of slow cold-water deposition.

The maximum exposed thickness of the Cattle Creek Formation is about 400 feet (S14, Pl. 9A). The subsurface correlation of the unit is shown in Plates 8A and 8B; in AOE No. 1 (Reids Dome) the formation is 1625 feet thick. We have not been able to confirm the erosional unconformity at or near the top of the Cattle Creek Formation (see Cundill & Meyers, 1964, p. 136).

The Cattle Creek Formation is richly fossiliferous (see App. 1). The assemblage belongs to Fauna II and possibly Fauna I of Dickins et al. (1964), and indicates a Lower Permian age.

Stanleigh Formation

The name, as Stanleigh Shale, was first published and defined by Phillips (in Hill & Denmead, 1960). The type locality is near Stanleigh homestead (Phillips, 1959). The section in Orion Creek, several miles north of Stanleigh homestead (S8-9, Pl. 9A), is designated as the type section.

The name Dilly beds of Jack & Etheridge (1892) and the term Dilly Marine Stage of Reid (1930) were used for the Permian rocks about 6 miles north of Springsure near Dilly homestead. Patterson (1955) used the term Dilly Shales synonymously for the Stanleigh Formation, and in the Springsure Anticline, including the area north of Springsure, he separated the Dilly Shales from the Orion Shales. Similarly, during the present survey, the Dilly beds have been subdivided into the Stanleigh and Orion Formations.

Phillips (1959), on the other hand, mapped the Dilly beds as Cattle Creek Shale. Because it appears that the name Dilly was originally used for the stratigraphical interval represented by both the Orion and Stanleigh Formations it has been allowed to lapse in this Report.

The Stanleigh Formation crops out in the Springsure Anticline in both the Springsure and Emerald Sheet areas (Pl. 7A); much of it is covered by Tertiary basalt. The formation, which is composed mainly of soft sediments, is poorly exposed, and generally forms soil-covered, featureless country. The sandstone beds stand out as low strike ridges. On the air-photographs the formation is difficult to distinguish from the underlying Orion Formation, but in the type area it contrasts with the prominent dark tone of the overlying Staircase Sandstone. The trend of the bedding is emphasized by alternating zones of different types of vegetation.

The best exposures occur in Orion Creek (S8-9, Pl. 9A); Springsure Creek, about 8 miles north of Springsure; and Little Oaky Creek (S18, Pl. 9A). The outcrops consist mainly of sandstone, which is apparently predominant in the lower half of the formation. The sandstone consists of lithic and quartz grains, some tuff, and a little feldspar and biotite; some is calcareous (Fehr, 1962). It is granular and pebbly in places, and commonly cross-bedded. The large unexposed areas are probably underlain by soft argillaceous rocks, which are only exposed in the creeks. The argillaceous rocks consist mainly of dark grey to dark blue poorly bedded silty carbonaceous shale. Some of the beds are micaceous; some contain gypsum and jarosite along the bedding planes and joints; others contain ferruginous accretions, up to 2 feet across, containing pebbles and fossil shells. A bed of coquinitic limestone, the '<u>Eurydesma</u> Limestone', is exposed near the base of the Stanleigh Formation 6 miles north of Springsure near Dilly homestead.

The Stanleigh Formation conformably overlies the Orion Formation with a transitional contact (Fig. 7). The boundary is chosen at the lowest beds lacking coaly beds, rootlets, and plant leaf beds, or containing shelly fossils.

The Stanleigh Formation was mainly deposited in a marine environment which gradually replaced the fresh water of the Orion Formation. The dark gypsiferous shale was probably deposited in restricted marine basins, and the cross-bedded sandstone with shelly fossils in a delta. The interbedding of sandstone and shale is probably due to migration of the sand deltas.

In the type area, the formation is at least 1460 feet thick (the base is probably 100 to 200 feet stratigraphically below the base of the type section (S8-9, Pl. 9A)). The thickness to the north is probably about the same, as nearly 1000 feet of section was measured in Little Oaky Creek (S18, Pl. 9A), and there is probably several hundred feet of section under the Tertiary basalt immediately to the west.

The marine fossils indicate a Lower Permian age (app. 1). <u>Glossopteris</u> is also present (App. 3).

Staircase Sandstone

The term Staircase Sandstone was introduced by Reid (1930) for the sandstone in the Staircase Range. The section along the Springsure-Duaringa Highway where it crosses the range near Staircase Creek is designated as the type section (S10, Pl. 9A).

The formation crops out in the Springsure Anticline. In the western limb of the Springsure Anticline from Dalmally homestead to near Dilly Pinnacle, several miles north of Springsure, it is covered by Tertiary basalt. The sandstone forms rocky dip slopes and natural staircases in the type area, in the Staircase Range. The formation has a dark tone on the air-photographs because of dense timber cover, but to the north it becomes progressively more difficult to distinguish from the Sirius and Stanleigh Formations.

The formation consists mainly of cross-bedded quartzose sandstone with lithic fragments and feldspar in the type area (S10, Pl. 9A). To the north and south, it is less sandy, and contains numerous soft silty and shaly intervals (S11, S13, S34, Pl. 9A).

The Staircase Sandstone grades conformably from the underlying Stanleigh Formation; the lowest dominantly quartzose sandstone is taken as the boundary.

The formation has a uniform thickness of about 700 feet between the type area (S10, Pl. 9A) and Aldebaran Creek (S11, Pl. 9A); to the north it ranges from 420 feet in Little Oaky Creek (S13, Pl. 9A) to 625 feet in Minerva Creek (S34, Pl. 9A). North and south of the type area the formation becomes more argillaceous. To the north the direction of the currents indicate a southwesterly provenance, but to the south the provenance was northwesterly; in the type section, the currents were from the west. The sandstone to the south is well sorted and contains very little feldspar. The type area was probably the site of a sandy delta which entered the Denison Trough from the west. The argillaceous material was carried to the north and south by currents flowing parallel to the north-south axis of the Denison Trough. During intervals of rapid growth of the delta, sand was carried by currents north and south of the type area.

A few casts of marine pelecypods have been found near the top of the formation (S11, Pl. 9A); casts of logs and plants of Lower Permian age are also present (App. 3). The formation lies between the Lower Permian (fossiliferous) Stanleigh and Sirius Formations.

Sirius Formation

The term Sirius Shales was first published by Webb (1956) in a review based mainly on the stratigraphy of Patterson (1955), who had defined the formation as the interval between the Staircase and Aldebaran Sandstones. The term Gypseous Marine Stage was first used by Reid (1930) (Table 3); he inferred that the type area was in Staircase Creek and the type section in Staircase Creek immediately south of the Springsure-Duaringa Highway (S12, Pl. 9A). The name is derived from Mount Sirius, a basalt mesa, in the type area.

The formation crops out in the flanks of the Springsure Anticline; it is poorly exposed in the depression between ridges of the Staircase and Aldebaran Sandstones. The best exposures are found in meanders of entrenched creeks. On the air-photographs the formation has a soft grey tone in contrast to the dark pattern of the enclosing sandstones; the trend of the bedding is rarely visible.

The formation consists of interbedded shale, siltstone, and fine-grained poorly bedded lithic sandstone. The sandstone is commonly brown and soft, and has an argillaceous matrix. The grey and buff siltstone beds commonly contain gypsum and jarosite, and some of the siltstone is calcareous. Grey and bluish shale and mudstone are commonly interbedded and interlaminated with siltstone. Scattered pebbles and cobbles occur in the basal beds. Worm burrows are present, generally in siltstone.

The formation rests conformably on the Staircase Sandstone with a sharp change in lithology in the type area; the contact is possibly locally disconformable.

The Sirius Formation was deposited mainly in the sea. The presence of gypsum and coal indicates restricted shallow water. The poor sorting of much of the sediment suggests rapid deposition by sediment-laden currents.

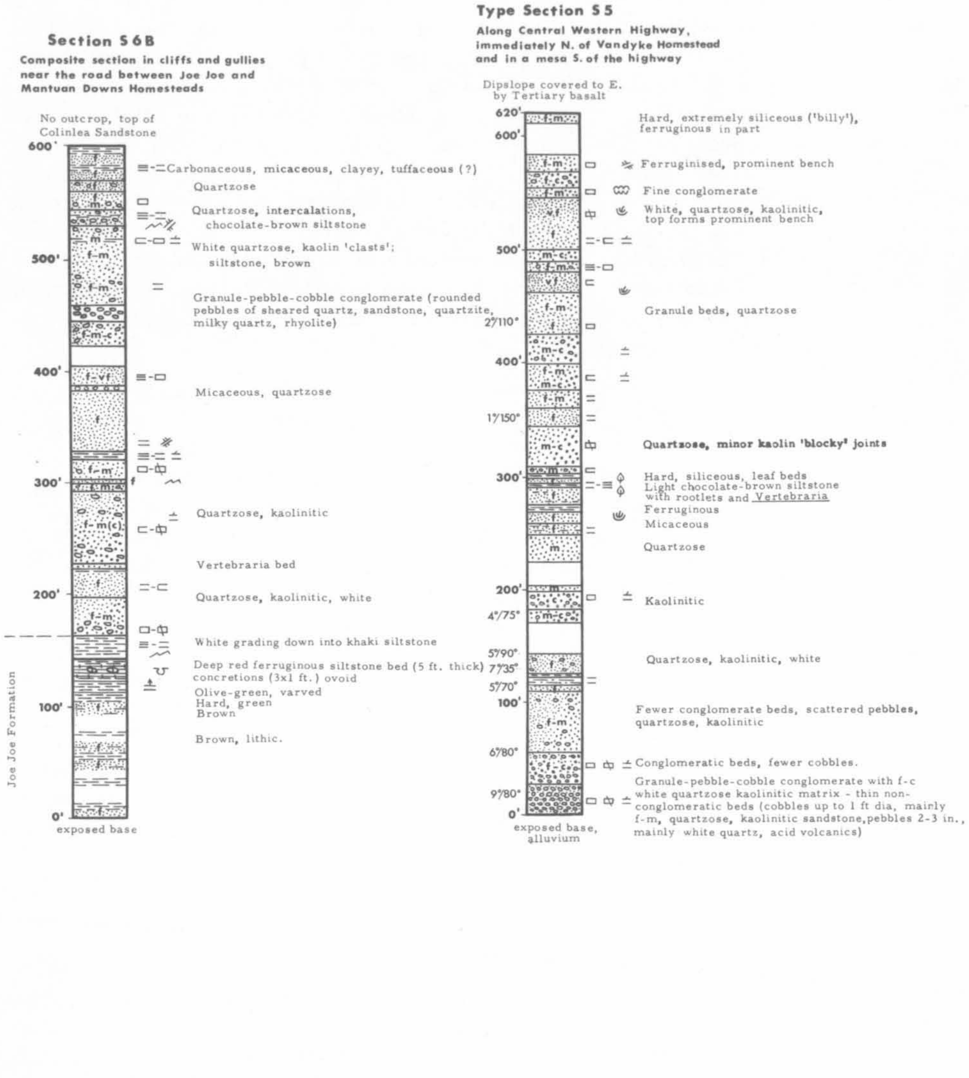
Section S6B
Composite section in cliffs and gullies near the road between Joe Joe and Mantuan Downs Homesteads
No outcrop, top of Colinlea Sandstone
600'
500'
400'
300'
200'
100'
0'
exposed base
Joe Joe Formation
Carbonaceous, micaceous, clayey, tuffaceous (?)
Quartzose
Quartzose, intercalations, chocolate-brown siltstone
White quartzose, kaolin 'clasts'; siltstone, brown
Granule-pebble-cobble conglomerate (rounded pebbles of sheared quartz, sandstone, quartzite, milky quartz, rhyolite)
Micaceous, quartzose
Quartzose, kaolinitic
Vertebraria bed
Quartzose, kaolinitic, white
White grading down into khaki siltstone
Deep red ferruginous siltstone bed (5 ft. thick) concretions (3x1 ft.) ovoid
Olive-green, varved
Hard, green
Brown
Brown, lithic.
f
f-m
f-vf
f-m-c
f-m(c)
Type Section S5
Along Central Western Highway, immediately N. of Vandyke Homestead and in a mesa S. of the highway
Dipslope covered to E. by Tertiary basalt
620'
600'
500'
2°/110°
400'
1°/150°
300'
200'
4°/75°
5°/90°
7°/35°
5°/70°
100'
6°/80°
9°/80°
0'
exposed base, alluvium
Hard, extremely siliceous ('billy'), ferruginous in part
Ferruginised, prominent bench
Fine conglomerate
White, quartzose, kaolinitic, top forms prominent bench
Granule beds, quartzose
Quartzose, minor kaolin 'blocky' joints
Hard, siliceous, leaf beds
Light chocolate-brown siltstone with rootlets and Vertebraria
Ferruginous
Micaceous
Quartzose
Kaolinitic
Quartzose, kaolinitic, white
Fewer conglomerate beds, scattered pebbles, quartzose, kaolinitic
Conglomeratic beds, fewer cobbles.
Granule-pebble-cobble conglomerate with f-c white quartzose kaolinitic matrix - thin non-conglomeratic beds (cobbles up to 1 ft dia, mainly f-m, quartzose, kaolinitic sandstone, pebbles 2-3 in., mainly white quartz, acid volcanics)
vf
m-c
f-c

Figure 8

The formation is 350 feet thick in the type area. It appears to be thinner to the north (S18, S34, Pl. 9A), and in the southern part of the Springsure Anticline.

The Lower Permian marine fossils from the Sirius Formation are listed in Appendix 1.

Colinlea Sandstone

Shell geologists (SQD, 1952) used the term Colinlea Series for the beds between the Joe Joe Formation and the Mantuan Productus Bed; Hill (1957) used the name Colinlea Formation for the same unit. During the present survey, the upper part of the interval, including the Mantuan Productus Bed, was identified as the Peawaddy Formation (as defined in the Reids Dome/Consuelo Anticline area), and the lower part, which consists mainly of quartz sandstone and which alone crops out in the type locality, is now referred to as the Colinlea Sandstone. The type area is along the Central Western Highway, to the north of Vandyke homestead, on Colinlea holding. Section S5 (Fig. 8) is designated as the type section; the uppermost part of the unit is concealed by Tertiary basalt. The Colinlea Sandstone crops out extensively in the northern half of the Sheet area and farther north and west in the Emerald and Tambo Sheet areas (Exon & Kirkegaard, 1965). Its extent to the east is obscured by Tertiary basalt. The Colinlea Sandstone forms prominent white cliffs several miles south of Echo Hills and Joe Joe homesteads; the basal part crops out in the upper part of cliffs up to 600 feet high, with numerous outliers in the buttes and mesas to the north. The ridges in the deeply incised area to the south of the cliffs have a herringbone pattern. The tone on the air-photographs is dominantly dark owing to dense growth of small trees. The dip-slopes and trend of the bedding are clearly discernible on the air-photographs.

The Colinlea Sandstone comprises fine to medium-grained quartz sandstone and granule-pebble-cobble conglomerate, grading to pebbly sandstone; conglomerate beds occur at intervals throughout the section, but are most common near the base; they are rare near the western boundary of the Sheet area. The pebbles and cobbles consist mainly of milky quartz and fine quartz sandstone, with subordinate quartzite, chert, and acid volcanics. The sandstone outcrops are porous and commonly contain some kaolinitic matrix; the sandstone cuttings from BMR No. 6 contain a high proportion of white kaolinitic matrix. Thin interbeds of soft purplish siltstone commonly contain plant fossils. South of Nandowrie Needle, a basal conglomerate contains ferruginized logs. The sandstone is commonly thick to medium-bedded, particularly near the base, and tends to be thinly bedded to laminated towards the top; cross-bedding and festoon-bedding are common.

In the type section (Fig. 8) the upper part contains very thick-bedded fine and even-grained festoon-bedded sandstone which forms prominent benches. A sandstone bed about 530 feet above the base of the type section forms a rocky bench around a mesa. The southern face of the bench is covered with an encrustation of alunogen, about half an inch thick (Richards, 1918b).

A 2-foot bed of sandstone, about 60 feet above the base of the formation in the cliffs south of Joe Joe homestead, contains abundant Vertebraria (Figs 6, 8, S6A, S6B).

In the west, the Colinlea Sandstone has a regional dip of 1° to 2° to the south and south-southwest; it is broadly folded in the Fairview Anticline and at the southern end of the Nogoa Anticline. The unit is bounded by faults east of the Nogoa Anticline; they are rejuvenated faults in the Devonian-Carboniferous sequence. The Colinlea Sandstone unconformably overlaps the Joe Joe Formation, Ducabrook Formation, Raymond Sandstone, Telemon Formation, and Dunstable Formation, and the unconformity becomes more prominent to the east. West of the Nogoa River, it is disconformable on the Reids Dome Beds and Joe Joe Formation.

The Colinlea Sandstone represents a sheet of fluvial sand deposited on the stable Springsure Shelf. In the west, the orientation of the cross-bedding suggests a west to southwesterly provenance for the lower part of the formation, and a south to southeasterly provenance for the upper part. In the type area a few measurements of the direction of the cross-bedding indicate a southwesterly provenance for the lower part and a northwesterly and easterly provenance for the upper part. The numerous pebbles of fine-grained quartzose sandstone were possibly derived from the Raymond Sandstone, and the pebbles of volcanic rocks from the Dunstable Formation. Many of the pebbles may have been derived from the conglomerates in the Joe Joe Formation.

The Colinlea Sandstone apparently represents slow sedimentation on the Springsure Shelf, during the interval from the base of the middle conglomerate member of the Aldebaran Sandstone to the top of the Catherine Sandstone in the Devonian Trough. The Ingelara Formation probably wedges out west of the Springsure Anticline under the Tertiary basalt, although a thin, apparently soft interval, shown on air-photographs by a persistent trend in the bedding south of Hillview homestead (Pl. 6), is possibly a representative of the Ingelara Formation. The petrography of the lower and upper parts of the Colinlea Sandstone is similar to the Aldebaran and Catherine Sandstones respectively (Bastian, 1965a). The correlation is based on palynological evidence (Evans, pers. comm.).

In the type area, 620 feet of section is exposed, but the top of the formation is obscured by Tertiary basalt. Along the road between Mantuan Downs and Joe Joe homesteads the Colinlea Sandstone is 440 feet thick; it is estimated to be about 800 feet thick near Highmounts homestead, near the southern end of the Nogoa Anticline.

The plant fossils are probably Lower Permian (App. 3), and the spores from BMR No. 6 are also Lower Permian (Evans, pers. comm.).

Aldebaran Sandstone

The name Aldebaran Sandstone was first used by Reid (1930) for the massive siliceous sandstones between Aldebaran and Staircase Creeks. Reid mapped the Aldebaran Sandstones only in the Springsure Anticline. He believed them to be older than his Serocold Sandstones in the Serocold-Consuelo Anticline area (see Table 3). Since Reid's work, the name Aldebaran Sandstone has been used for both his units by most workers, apart from Phillips (1959; and in Hill & Denmead, 1960), who used the name Serocold Sandstone. In the east limb of the Springsure Anticline, Reid mapped the interval from the base of the Aldebaran Sandstone to the top of the Catherine Sandstone as Aldebaran Sandstones and Phillips mapped the same interval as Serocold Sandstone. The name Aldebaran Sandstone is here used for the interval between the top of the Sirius Formation and the base of the Ingelara Formation, as proposed by Reid. The section exposed in the south branch of Aldebaran Creek is designated as the type section (S15, Pl. 9A).

The unit crops out in the Springsure, Serocold, and Consuelo Anticlines. The outcrop in the west limb of the Springsure Anticline, a few miles north of Mount Catherine, is terminated to the north by overlapping Tertiary basalt, but in the east limb it is continuous into the Emerald Sheet area (Pl. 7A). It does not crop out east or south of the Springsure Sheet area.

The Aldebaran Sandstone forms prominent rocky cuestas and ridges, particularly in Reids Dome. The sandstone is well exposed in magnificent cliffs and gorges. The dip-slopes commonly support a dense cover of timber which has a dark tone on the air-photographs, quite distinct from the lighter tones of the underlying and overlying softer formations. The structures in the Aldebaran Sandstone are clearly visible on the air-photographs.

The formation has been subdivided into three members which have been mapped but not formally named (Pl. 7A, 7B). The lower sandstone member consists of fine to medium-grained feldspathic quartzose sandstone with interbedded carbonaceous siltstone. The sandstone contains granules and pebbles of indurated fine sandstone, siltstone, and milky quartz. Some sandstone beds are riddled with worm tubes (see section S16, Pl. 9A). In the basal part of the member, some of the sandstone beds have contorted bedding and others have been fragmented and are infiltrated by the underlying siltstone; also pebbly sandstone beds truncate thinly bedded sandstone with carbonaceous silty laminae. These features, which are related to slumping and the encroachment of bodies of sand, are well exposed in Little Gorge Creek in the northeast limb of Reids Dome (section S16, Pl. 9A). The member contains several intervals of lutite in the northern part of the Springsure Anticline; one of these intervals at the top of the unit was drilled (BMR No. 37); the interval consists of dark mudstone with a thin coal seam (Mollan, Exon, & Forbes, 1965b).

The middle conglomerate member consists of cross-bedded conglomeratic quartzose sandstone with beds of conglomerate. The pebbles consist of fine indurated sandstone and siltstone, milky quartz, and subordinate chert and acid volcanic rocks. The cross-bedding consists of truncated high-angled foresets in units several feet thick; fine-grained thin-bedded sandstone forms the thin bottomset units; the topset beds are rarely preserved. Conglomerate is common at the base of foreset beds. Festoon-bedding and scour channels are present. In Little Gorge Creek (section S16, Pl. 9A), the basal conglomerate contains clasts of soft shale and siltstone up to the size of boulders.

The topmost transition member consists of thinly interbedded quartzose sandstone and siltstone which is commonly micaceous and fissile; conglomeratic sandstone is rarely present. Worm tubes and oscillation ripple marks are common. The lithology of specimens from the measured sections in the Aldebaran Sandstone has been described by Bastian (1965a).

The sandstone member is 900 to 1100 feet thick in Reids Dome (Pl. 9A), 300 to 400 feet thick in the northern part of the Springsure Anticline (Pl. 9A), but probably thinner to the south. The conglomerate member is 300 to 600 feet thick in Reids Dome, and 600 to 800 feet in the Springsure Anticline. The transition member is 150 to 250 feet thick (Pl. 9A).

The sandstone member was deposited in a brackish deltaic environment which gradually replaced the marine environment of Cattle Creek times. Deltaic sands advanced on the depositional area, probably from the west. Their deposition alternated with periods of slow silty sedimentation related to subsidence.

The conglomerate member represents a period of quartzose sand and gravel sedimentation; subsidence of the Denison Trough was sufficient to keep pace with the influx of sediments deposited from torrential streams. The sandstone member was slightly eroded in places before deposition started. The deposition of the conglomerate member was accompanied by slight subsidence of the Springsure Shelf, which received a sheet of alluvial sand (the lower part of the Colinlea Sandstone). The regression of the sea during this period was not related to uplift of the Denison Trough, but to a slower rate of subsidence than in Cattle Creek time. The trough was probably partly separated from the sea and the water was brackish because of a high rate of inflow of fresh water from torrential streams.

The provenance of the quartzose conglomerate was different from that of the conglomeratic beds in the Cattle Creek and Ingelara Formations. The indurated fine quartzose sandstone was possibly derived from the Raymond Sandstone and Mount Hall Conglomerate and the milky quartz from the Anakie Metamorphics. The conglomerate member represents high-energy much reworked clastic material which was probably to the north of the present outcrop area of the Colinlea Sandstone, because the basal part of the formation appears to be equivalent to the conglomerate member of the Aldebaran Sandstone, and because the cross-bedding in the Aldebaran Sandstone suggests deposition from currents from the north and west.

The transition member represents a gradual return to marine conditions in the Denison Trough, which culminated in Ingelara time. The environment of deposition of the transition member was paralic; sand and silt were deposited alternately in shallow water, subject to marine incursions.

The sediments are typical of those of the neritic regime, and suggest that the Denison Trough was subsiding more rapidly, relative to the growth of the sedimentary pile, than when the conglomerate was laid down.

The Aldebaran Sandstone conformably overlies the Sirius Formation in the Springsure Anticline and the Cattle Creek Formation in Reids Dome. The boundary with the Cattle Creek Formation is transitional; the base of the lowest quartzose sandstone bed is taken as the boundary. The conglomerate member overlies the sandstone member apparently with structural conformity, but in Little Gorge Creek the presence of large clasts of shale and siltstone in the base of the conglomerate member suggests a local disconformity. Near Narraway homestead, the conglomeratic member appears to overlap the sandstone. In this area it is hardly distinguishable lithologically from the lower part of the Colinlea Sandstone immediately to the west. The base of the conglomerate member is a well defined boundary which is a useful marker in the northern part of the Springsure Anticline, where the underlying formations are not easily distinguished.

The transition member conformably and transitionally overlies the conglomerate member; the top of the highest thickly cross-bedded conglomeratic sandstone is regarded as the boundary.

The Aldebaran Sandstone is Lower Permian because it lies between formations with lower Permian marine faunas and contains lower Permian spores (Evans, pers. comm.). Terrakea has been found in the transition member by geologists of Mines Administration Pty Ltd. Terrakea was also found in the formation in Planet Warrinilla No. 1 well. Permian plants are also present (App. 3).

Ingelara Formation

The term Ingelara Stage was first published in a table in Raggatt & Fletcher (1937) which described the interval between the Catherine and Aldebaran Sandstones; Hill (1957) used 'Ingelara Formation' for the same interval. Reid (1930) used the term Coral Stage for the interval between his Aldebaran and Catherine Sandstones. The name is derived from Ingelara homestead, and Hill (1957) states that it 'is well exposed on the Ingelara Property', thus implying that this is the type area. As the Catherine Sandstone is missing in this area, the area about 3 miles north-northwest of Ingelara homestead is proposed as the type area, and measured section S20 as the type section (Pl. 9A).

The formation crops out in the flanks of the Springsure, Consuelo, and Serocold Anticlines and forms a narrow corridor between cuestas of the Aldebaran and Catherine Sandstones. It is poorly exposed, except in deeply entrenched creeks.

The formation comprises mainly poorly sorted and poorly bedded conglomeratic sandy siltstone and silty mudstone. The lutites generally contain carbonized plant fragments and coal grains; in places they are pyritic, and contain lenses, bands, and aggregates of gypsum and bands of jarosite. Calcareous concretions with shelly fossils are common in the Reids Dome area; boulders of granite, porphyritic volcanics, and low-grade metamorphics are present, especially in the southern part of Reids Dome.

The Ingelara Formation overlies the Aldebaran Sandstone with a transitional boundary. Hill (1957) and Phillips (in Hill & Denmead, 1960) included the transition member of the Aldebaran Sandstone in the Ingelara Formation in Reids Dome, but it was included in the Aldebaran Sandstone in the Springsure Anticline. The boundary between the Aldebaran Sandstone and the Ingelara Formation is taken at the top of the highest quartzose sandstone bed (Pl. 9A).

The Ingelara Formation represents rapid marine sedimentation related to an increased rate of subsidence in the depositional area; and marks a return to an environment in the Denison Trough similar to that in Cattle Creek times.

The formation is 120 feet thick in the proposed type area (S20, Pl. 9A). The maximum measured thickness is 535 feet near Mount Catherine (S15, Pl. 9A), where apparently there is a local thickening; elsewhere it is seldom over 200 feet thick.

The rich shelly fauna collected from the Ingelara Formation during the present survey is listed in Appendix 1; it indicates a Lower Permian age.

The origin of large blocks of igneous and metamorphic rocks and indurated sediments in the Cattle Creek and Ingelara Formations is uncertain. Hill (1957) and others have suggested that the blocks were derived from icebergs. Close inspection of several blocks (Pl. 4, fig. 1) revealed no conclusive evidence of depression of the bedding which could be expected if the blocks were dropped into unconsolidated bottom sediment.

Both formations consist of poorly sorted and almost unbedded clastic sediments. The formations were possibly deposited rapidly and the blocks may have been derived from a nearby landmass, and transported into the Denison Trough by dense sediment-laden currents. The blocks of igneous rocks weather rapidly on exposure and it seems unlikely that they suffered much subaerial transport.

On the other hand, the presence of the '_Eurydesma_ limestone' in the Cattle Creek Formation is an indication of a cold-water environment.

Catherine Sandstone

The term Catherine Sandstones was first used by Reid (1930) for 'grey and red sandstone ... about 4 miles S.S.E. of Mount Catherine'. Shell geologists (SQD, 1952) used the term Catherine Series, but Hill (1957) reverted to the name Catherine Sandstone. The present survey has shown that Shell geologists, in addition to the quartz sandstone seen by Reid, included 400 to 500 feet of silt, shale, and lithic sandstone (Peawaddy Formation) in their Catherine Series. The additional beds crop out in Reids Dome, but they are mainly concealed by Tertiary basalt at Reid's Mount Catherine locality. The Mantuan _Productus_ Bed, a lenticular coquinitic horizon near the top of the Peawaddy Formation, is absent in the Mount Catherine area. In this Report the name Catherine Sandstone is used for the Catherine Sandstones as defined by Reid. The formation consists of 270 feet of dominantly quartz sandstone in the type area (S30, Pl. 9A).

The Catherine Sandstone forms narrow dissected ridges on the flanks of the Springsure, Serocold, and Consuelo Anticlines. On the western flank of the Springsure Anticline, several miles north of Mount Catherine, the Catherine Sandstone is concealed by Tertiary basalt; it does not crop out farther north. South of Mount Catherine inliers are exposed through the dissected basalt sheet. On the east flank of the Springsure Anticline (Pl. 7A), the Catherine Sandstone crops out in the Springsure Sheet area and to the north in the Emerald Sheet area.

It consists predominantly of quartzose sandstone with 5 to 10 percent of potash feldspar in places (Bastian, 1965a). Much of the sandstone is fine to medium-grained and well sorted. Low-angle cross-bedding is common and small pebbles and granules are present in the foreset beds. Bastian (op. cit.) has identified significant amounts of muscovite, sericite, and chert, and a little glauconite, tourmaline, and zircon. The sandstone beds are probably separated by poorly exposed silty intervals in the Mount Catherine area (S15, Pl. 9A). The Catherine Sandstone has a dark tone on the air-photographs because of the dense cover of timber.

The Catherine Sandstone overlies the Ingelara Formation, transitionally in the Mount Catherine area, but with a distinct boundary in Reids Dome. It is overlain by the Peawaddy Formation, with a sharp structurally conformable boundary. It wedges out near the southern end of Reids Dome about 5 miles south of Consuelo Creek and 8 miles south of Mount Serocold; the wedge-out can be seen in the field and on the air-photographs. Measured section S20 (Pl. 9A), immediately north of the wedge-out, includes 20 feet of Catherine Sandstone. The formation does not reappear at the surface farther south.

We believe that the wedging out of the Catherine Sandstone is related to erosion before the Peawaddy Formation was laid down. Other workers (Cundill, Meyers, & Associates, 1963, 1965; Power, 1966) hold that the wedging out is a depositional feature related to the development of the Catherine Sandstone as a bar sand. The main implications of these interpretations are mentioned in the discussion on the subsurface regional correlation of the Permian sequence (p. 45). Three field observations support erosion as the main cause of the wedge-out:

(i) The thinning of the interval from the top of Peawaddy Formation to the base of the Ingelara Formation towards the southern end of Reids Dome corresponds to the reduction in thickness of the Catherine Sandstone.

(ii) The Peawaddy Formation is laterally persistent, and rests in turn on the Catherine Sandstone and, south of the wedge-out, on the Ingelara Formation. The sharp contacts between the Catherine Sandstone and the Peawaddy Formation and between the Ingelara and Peawaddy Formations (S19, Pl. 9A) suggest a disconformity. At the boundary in Dry Creek, southern Reids Dome, the Peawaddy Formation has a 4-foot lithic sandstone with a pebble band at the base.

(iii) There is no evidence in the field or on the air-photographs of any lateral equivalent of the Catherine Sandstone.

The Catherine Sandstone represents the last stage of sedimentation in the Denison Trough as a distinct depositional province. The sandstone was deposited in shallow-marine and paralic environments. Low-angle cross-bedding and good sorting of the sand suggest that the unit represents, in part, poorly developed sand bars. The Catherine Sandstone was eroded to the south and east (see p.47) during a period of regional tectonic adjustment in the Bowen Basin.

The Catherine Sandstone is 270 feet thick in the type area; elsewhere the measured thicknesses range from 20 to 450 feet (Pls 9A, 9B).

The formation contains several marine fossiliferous horizons (App. 1) referable to the Lower Permian Fauna III of Dickins et al. (1964).

Peawaddy Formation

The name Peawaddy Formation was introduced by Mollan, Kirkegaard, Exon, & Dickins (1964) for about 500 feet of lithic sandstone and siltstone above the Catherine Sandstone in the eastern part and above the Colinlea Sandstone in the western part of the Springsure Sheet area. It is overlain by the Black Alley Shale. The Peawaddy Formation contains the very fossiliferous coquinitic sandstone and siltstone lenses of the Mantuan Productus Bed at, or near, the top. The type area is Reids Dome and Consuelo

Anticline; the type section is in Peawaddy Creek, after which the formation is named, in the west limb of the Consuelo Anticline (S22, Pl. 9B). Table 3 shows the nomenclatural history of the sequence.

The formation crops out in the Springsure, Serocold, and Consuelo Anticlines, and in a sinuous belt between Wealwandangie and Fairview homesteads. In the east, the outcrops form low smoothly rounded ridges with a fairly even cover of timber, which form a sharp contrast, particularly in the east flank of Reids Dome, with the sharp, rocky, densely timbered cuestas of the Catherine Sandstone. On the air-photographs the Peawaddy Formation has a light even tone compared with the darker tone of the Catherine Sandstone. A dendritic drainage pattern is developed on low-dipping beds of the Peawaddy Formation at the southern end of Reids Dome, about 2 miles northwest of Ingelara homestead. To the west of the Springsure Anticline, the Peawaddy Formation forms gently undulating country. To the west of Tanderra homestead, where the formation is readily distinguished from the Colinlea Sandstone on the air-photographs, the trend of the bedding in the lower part of the formation can be traced for several miles, but to the east, it is more difficult to distinguish between the two formations.

The Peawaddy Formation is deeply weathered and poorly exposed, and fresh exposures are found only in gullies and creeks. The formation consists mainly of siltstone, carbonaceous shale, and lithic quartz sandstone, but only the sandstone, which is commonly calcareous and rarely conglomeratic, is generally exposed. Lithic sandstone is generally predominant at the top of the formation. The lithic grains in the sandstone consist mainly of fragments of volcanic rocks, but fragments of schist and indurated sediments are also present. About 10 percent of feldspar and a little mica and glauconite may be present. The matrix is commonly chloritic and calcareous.

Much of the formation consists of thinly interbedded and interlaminated siltstone and carbonaceous shale; they are commonly micaceous and contain abundant plant debris. In the west (S26, Pl. 9B) the clayey siltstone contains cobbles of indurated silicified sediments (probably hornfels), slate, and fine-grained greenish volcanics. Similar boulders were encountered in BMR No. 1 (Arman, 1965a). Gypsum and jarosite(?) occur along the bedding planes in the siltstone and in the interlaminated shale, notably in the west. Vertical worm burrows, filled with black mudstone, are common in the siltstone and sandstone. Calcareous concretions are common in some of the siltstone. The lithology is illustrated by the measured sections in Plates 9A and 9B. Bastian (1964) has made a petrographic study of outcrop specimens from the formation.

The lithic quartz sandstone at the top of the Peawaddy Formation contains very fossiliferous to coquinitic lenses, with brachiopods, pelecypods, gastropods, corals, and bryozoans. In Sandy Creek, on the east flank of Reids Dome, the fossils occur mainly in siltstone (S24, Pl. 9B). The fossiliferous to coquinitic lenses are known collectively as the Mantuan Productus Bed, after the type exposure of a coquinite lens 4 miles north of Mantuan Downs homestead, near Maori Gully bore. The fossiliferous lenses of the Mantuan Productus Bed probably occur within a thin stratigraphic zone composed mainly of lithic quartz sandstone. Further detailed work may show that the sandstone can be mapped as a separate member. The name Mantuan Productus Bed, however, seems best applied only to the fossiliferous coquinitic lenses.

The Peawaddy Formation is probably disconformable on the Catherine Sandstone in the east and disconformable on the Colinlea Sandstone in the west. The contact with the overlying Black Alley Shale was observed at several localities (Pl. 9B); the sharp lithological break suggests that they are possibly disconformable.

The Peawaddy Formation is extensive and fairly uniform in thickness in the Springsure Sheet area. It transgresses the Catherine Sandstone and rests on the Ingelara Formation at the southern end of Reids Dome; and probably unconformably transgresses the

Ingelara Formation to the east and south (Pls 8A, 8B). The formation was deposited in a shallow basin of much greater extent than the Denison Trough; marine conditions prevailed for at least part of the time, particularly in the last stages when the Mantuan Productus Bed was deposited. The sandstone appears to have been derived from a granitic and volcanic terrain because it contains much feldspar, and grains of granitic and volcanic rocks. Tuff is probably also present. The siltstone with black shaly laminations is commonly cross-laminated, and contains abundant carbonized plant debris, mica, pyrite, gypsum, and jarosite(?) along the bedding planes. Worm tubes are common in some of the siltstone. These features suggest that the environment at times was shallow, brackish, and restricted.

The origin of the cobbles and boulders of hornfels, granite, and schist in the argillaceous sediments in the Springsure Shelf area is uncertain; they were possibly derived from the Anakie Metamorphics.

The Peawaddy Formation is 450 feet thick in the type section (S22, Pl. 9B). The thickness appears to be fairly constant across the Sheet area, and for example near Tanderra homestead in the Springsure Shelf it is nearly 450 feet thick (S26, Pl. 9B).

The Peawaddy Formation contains the richly fossiliferous lenticular Mantuan Productus Bed and several less fossiliferous lower horizons (Pl. 9B). The fossils are regarded as early Upper Permian (App. 1).

Black Alley Shale

We have divided the Bandanna Formation of Hill (1957), which was first published but not defined by Maxwell (1954), into the Black Alley Shale and the Blackwater Group. Hill noted the twofold lithological character of the Bandanna Formation, and referred to the two parts as the lower and upper parts. Use of formal names for these units appears to be the best way to express the stratigraphic significance of the Bandanna interval, especially in terms of its relationships with other parts of the Bowen Basin.

The Black Alley Shale is named from Black Alley Peak in the southeast corner of the Springsure Sheet (see Pls 6, 7B). The type section (S31, Pl. 9B) is in the main west branch of Dry Creek, about 2 miles southeast of Black Alley Peak.

The formation crops out in the flanks of the Serocold and Consuelo Anticlines, in the Wealwandangie Syncline, and in a sinuous belt from Goathland homestead to the western boundary of the Sheet, near Fairview homestead. The Black Alley Shale forms featureless grassy downs almost devoid of trees. Despite the poor exposures, the formation is readily recognized by the overlying heavy dark soil, associated with gilgais and small domed tumuli. On the air-photographs, the formation can be distinguished by its light tone and the presence of gilgais which form fan-like patterns.

The Black Alley Shale consists mainly of dark shale. It is characterized, especially in the lower part, by soft soapy clay beds which have been shown to be pure montmorillonite with excellent bentonitic qualities (Thompson & Duff, 1965). The clay beds are generally yellowish green, and are rarely over 2 feet thick and commonly less than 1 foot. They are exposed in the banks of entrenched creeks where their ability to facilitate landslips is apparent. The bentonitic clay readily expands on exposure, a feature which promotes the formation of small mounds in the soil cover.

The best exposures are in the southern part of Reids Dome, in the Early Storms Dome, and in the area south of Wealwandangie homestead. Several beds of tuff and tuffaceous shale with glassy shards have been found close to the clay beds (e.g., in Freitag Creek, near the junction with the Wealwandangie-Springsure road, and in a gully at the junction with the road to Carnarvon Gorge). Some tuff beds are partly altered to clay.

Thin hard ferruginous beds, minor siltstone, and rare sandy beds are present (Pl. 9B).

The Black Alley Shale is regionally conformable on the Peawaddy Formation; the boundary has been observed in the Early Storms and Bandanna Domes. The sharp junction between the lithic sandstone at the top of the Peawaddy Formation and the Black Alley shale suggests a hiatus in deposition.

The Black Alley Shale represents a transitional period of sedimentation between the marine Peawaddy Formation and the paludal Blackwater Group. Only the lower part of the formation contains horizons with marine(?) acritarchs. The argillaceous lithology, the presence of bentonite beds (probably derived from the alteration of tuffs), and 'swarms' of acritarchs indicate slow deposition in a silled basin, protected from strong currents. Furthermore, the presence of thin strongly ferruginous beds suggests periods of emergence. Horizons of fossilized logs and leaves at the top of the Black Alley Shale indicate the complete transition to paludal conditions.

The thickness of the Black Alley Shale is 310 feet in the type section, 300 feet near Mount Serocold (S27, Pl. 9B), and 488 feet on the western flank of the Early Storms Dome (S28, Pl. 9B). In the Wealwandangie Syncline it is probably about 300 feet thick. The maximum thickness is probably not more than 500 feet.

Plant fossils, acritarchs, and rare fish scales (see S31, Pl. 9B) are present.

Blackwater Group

The name Blackwater Group was introduced by Malone, Olgers, & Kirkegaard (1969) to cover a group of Upper Permian non-marine formations in the Duaringa Sheet area, because of the change in sedimentation and environment from the predominantly marine units of the Back Creek Group. The name Blackwater Group is used for the upper part of the Bandanna Formation instead of introducing a local name in the Springsure Sheet, because the interval designated as the Blackwater Group is almost certainly equivalent to part of the sequence in the type area, and because the interval in the Springsure area cannot be reliably equated with a specific interval in the type area. No attempt has been made to separate the group into the formations found in the type area, and it is possible that part or all of the Black Alley Shale is equivalent to part of the Blackwater Group.

The Blackwater Group has a similar distribution in outcrop to the Black Alley Shale. The group forms fairly featureless country with rare exposures. Separation from the Black Alley Shale is difficult, especially in the west where exposures are limited. On the air-photographs, the Blackwater Group can be distinguished by a slightly denser cover of timber, and the presence of several low strike ridges.

The Blackwater Group consists of a thinly interbedded sequence of greenish and commonly calcareous lithic sandstone, siltstone, carbonaceous shale, and coal seams. Sandstone is more common in the basal part of the group; in the low sandstone ridges provide useful marker beds at the base. Horizons of fossil logs occur in the basal sandstone beds; the logs are commonly weathered out at the surface (Pl. 4, fig. 2). Several extremely contorted beds of sandstone have been observed between undisturbed beds; they are well exposed in Freitag Creek about a mile south-southeast of Avoca homestead.

The group is characterized by the presence of coal seams (Pl. 5, fig. 1) and leaf beds; oil shale and minor beds of clay are present in the eastern flank of the Early Storms Dome (S35, Pl. 9B). Thin hard beds of ferruginous siltstone occur throughout the sequence.

The Blackwater Group is apparently conformable on the Black Alley Shale; the presence of fossil log horizons near the boundary suggests breaks in sedimentation, and the units are probably locally disconformable.

The Blackwater Group represents a period of predominantly paludal and lacustrine deposition; the sandstone beds with festoon bedding represent periods of fluviatile deposition. The thin interbedding of arenite, lutite, and coal indicates intermittent subsidence, and the contorted sandstone beds were possibly formed by sudden movements which disturbed an unconsolidated layer of sand.

The thickness of the Blackwater Group is 332 and 325 feet on the western (S28, Pl. 9B) and eastern (S35, Pl. 9B) flanks of the Early Storms Dome. A thickness of 240 feet has been measured west of Mount Serocold (S27, Pl. 9B). The thickness of 105 feet in measured section S31 (Pl. 9B) is tentative because of the paucity of outcrop; the top of the unit is possibly higher. The thickness is probably about 300 feet in the western part of the Sheet area.

The Blackwater Group contains a varied Glossopteris-Gangamopteris flora and other Upper Permian species (App. 3). Palynological evidence from exploratory well samples confirm the Upper Permian age (Evans, pers. comm.).

TRIASSIC

Rewan Formation and Brumby Sandstone Member

The term Rewan Series was first used by Shell geologists (SQD, 1952) and published as Rewan Formation by Isbell (1955). The name is derived from Rewan homestead; the type area is near the homestead, and the proposed type section is in small tributary of Consuelo Creek several miles to the north (S29, Pl. 9B). The formation crops out in the southeast quadrant of the Sheet area and in a sinuous belt extending east-west across the central part of the western half. In the northeast quadrant, the formation is largely covered by a thin sheet of Tertiary basalt.

The formation consists mainly of soft rocks with a thick cover of soil; outcrops are mainly found along streams. The country is featureless, with a variable cover of scrub and trees. On the air-photographs the tone ranges from light to very dark according to the changes in vegetation.

In the type area, the Rewan Formation is characterized and dominated by massive beds of reddish brown dense silty mudstone ('red-beds') which readily disintegrates; the bedding is poorly defined by thin green layers. In places, the green colour is apparently transitional with red. Green and khaki lithic quartz sandstone, which in places is coarse and granular, is common. The sandstone is commonly festoon-bedded; it contains layers of well rounded clasts of green mudstone and is strongly calcareous.

In the Cona Creek/upper Peawaddy Creek area the formation consists of thin-bedded multicoloured silty mudstone with poor shaly fissility; near the base, thin beds of khaki-green festoon-bedded lithic quartz sandstone with mud clasts are particularly common. Much of the silty mudstone is reddish brown, but numerous green, grey, and khaki interbeds are present. The reddish brown colour is predominant higher in the sequence.

In the western half of the Sheet area, the formation consists of fine-grained green and brown lithic quartz sandstone, which is commonly calcareous, and reddish brown silty mudstone. BMR No. 3 penetrated over 100 feet of the formation in this area (Arman, 1965a).

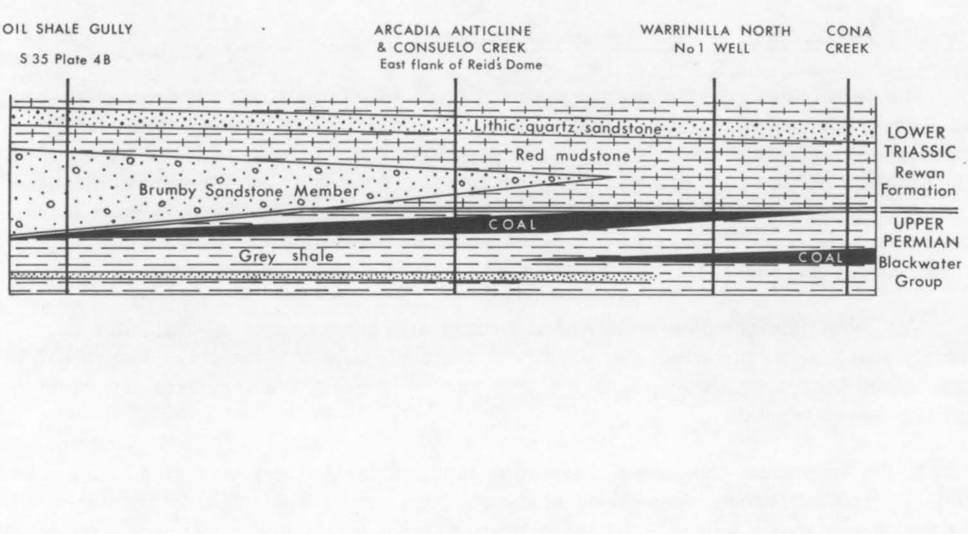
OIL SHALE GULLY
S 35 Plate 4B
ARCADIA ANTICLINE
& CONSUELO CREEK
East flank of Reid's Dome
WARRINILLA NORTH
No 1 WELL
CONA
CREEK
Lithic quartz sandstone
Red mudstone
Brumby Sandstone Member
COAL
Grey shale
COAL
LOWER
TRIASSIC
Rewan
Formation
UPPER
PERMIAN
Blackwater
Group

Figure 9

A lenticular pebbly sandstone at the base of the Rewan Formation, mapped in the Serocold Anticline (Pls 6, 7B), is regarded as the Brumby Sandstone of Reeves (1947), which crops out in the basal part of the Rewan Formation in the Arcadia Anticline (Taroom Sheet area).*

The Brumby Sandstone Member forms several prominent ridges in the southern part of the Serocold Anticline. The member consists of greenish coarse polygenetic sandstone with rounded pebbles and granules; in places the granules are angular. Clasts of volcanic rocks and green chert(?) are common; the amount of quartz in the sandstone is variable, but it rarely forms more than 50 percent of the total clasts.

The base of the Rewan Formation is difficult to define because its relationship with the Blackwater Group varies (see Fig. 9). The wedging out of the coal seam beneath the Brumby Sandstone Member in Oil Shale Gully to the north suggests a slight angular unconformity at the base of the member. Woolley (1944) detected a slight unconformity at the base of the Malta Grit and the Brumby Sandstone in the Arcadia Anticline. In AAO No. 7 (Arcadia) red-beds were found beneath the Brumby Sandstone (Derrington, 1957). In Consuelo Creek, on the east flank of Reids Dome, red mudstone and non-carbonaceous shale crop out between the Brumby Sandstone Member and the highest coal seam in the Blackwater Group. This interval contains Triassic spores (Evans, 1966). The continuous dipmeter log of the Warrinilla North No. 1 well (Meyers, 1963) suggests an unconformity at the base of red-beds of the Rewan Formation (Fig. 9). In Cona Creek, reddish and multicoloured shales have been observed above the grey carbonaceous shale sequence with coal seams (Fig. 9). Thus, the evidence suggests the presence of local disconformities and low-angle unconformities at the base of the Rewan Formation in the Springsure Sheet area to the east and southeast. The breaks in deposition are associated with the Permian-Triassic boundary.

The base of the Brumby Sandstone Member was mapped as the boundary with the Blackwater Group. In Consuelo Creek (and probably in other places where outcrop is lacking) the Triassic beds between the member and the Permian shale are included with the Blackwater Group in Plates 6 and 7B. Where the Brumby Sandstone Member is absent the boundary represents either the highest coal seam or the lowest reddish lutite.

The red-beds in the Rewan Formation probably derive their colour from fine hematitic sediment deposited in an oxidizing environment. The fine red material may have been derived from a hot humid region in which lateritic soils were being formed and continually removed by streams, or from a hot desert in which laterite was being eroded and transported mainly by wind. The red-beds were probably deposited in a steadily subsiding shallow non-marine basin. The presence of mud clasts in the festoon-bedded sandstone suggests that periods of desiccation were followed by the deposition of fluviatile sand. The high proportion of reworked vitric tuff in some of the sandstone (Fehr, 1962) indicates a volcanic provenance. Rapid deposition of the fine red mud or dust is indicated by the presence of fossil vertebrates which have been found at 'the Crater' on Rewan holding, in the Eddystone Sheet area (Mollan et al., in press). The presence of beds of green mudstone in the red-beds is attributed to reduction of iron under anaerobic conditions. In places, however, the colour may have been affected by diagenesis.

The Rewan Formation is 1690 feet thick in the proposed type section (S29, Pl. 9B). On the western flank of the Early Storms Dome the unit is 1860 feet thick (S28, Pl. 9B) and on the southwest flank of Reids Dome it is 1435 feet thick (S31, Pl. 9B). In Cona

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*Woolley's (1944) Malta Grit apparently represents a much thicker sequence, including the Brumby Sandstone, approximately equivalent to the lower part of the Rewan Formation of Hill (1957) - the Malta Grit has not been mapped because it is difficult to distinguish in much of the Springsure Sheet area.

Creek it is estimated to be about 400 feet thick; it thins out to the west and in the area south of Tanderra homestead (Pl. 6) it appears to be absent. To the west of Tanderra homestead the formation thickens to about 400 feet south of Mantuan Downs homestead.

The Brumby Sandstone Member is about 30 feet thick on the west flank of the Bandanna Dome (Pl. 7B); elsewhere it is between 10 and 20 feet thick.

Fossil logs and macerated plant remains are the only fossils found in the Rewan Formation in the Springsure Sheet area. Evans (1966) has identified Lower Triassic spores.

Clematis Sandstone (see Olgers et al., 1966)

The Clematis Sandstone crops out in the Rewan Syncline in the southern half of the Springsure Sheet area, in the west limb of the Serocold Anticline, in isolated areas between the Serocold Anticline and Tanderra homestead, and in a continuous belt from Tanderra homestead to the western boundary. It also crops out in the Baralaba, Tambo, Eddystone, and Duaringa Sheet areas. In the Rewan Syncline it forms pinkish red cliffs (Reid's 'Carnarvon Red Member'). The Clematis Sandstone forms benches beneath Tertiary basalt west and northwest of the Serocold Anticline. In the west it forms low poorly defined escarpments and ridges. Dense timber cover gives a dark tone on the air-photographs.

In measured sections S28 and S29 (Pl. 9B) the lower part consists of cliffs of white quartz sandstone interbedded with massive blocky mottled red silty mudstone, from which the red stain on the sandstone cliffs is derived. The sandstone is thick-bedded, cross-bedded, rarely graded bedded, fine to coarse-grained, and in places kaolinitic. Several of the sandstone beds are hard and ferruginous at the base. Some laminated grey siltstone is also present. Above the lower 150 feet (S29) are 150 feet of coarse thick-bedded conglomeratic sandstone with conglomerate beds which form a prominent cliff at Mount Carnarvon. The conglomeratic sandstone is followed by about 300 feet of quartz sandstone interbedded with brownish flaggy micaceous lithic and feldspathic fine sandstone, siltstone, and grey silty mudstone. The fine-grained blue-grey sandstone and siltstone contain well preserved plants (App. 3). Current ripple marks are common in the sandstone throughout the formation. Bastian (1965b) has described the petrography.

In the area between Reids Dome and Tanderra homestead, the formation generally consists of white coarse thick-bedded and cross-bedded sandstone and granule conglomerate. West of Tanderra homestead, fine-grained buff sandstone is predominant.

The Clematis Sandstone appears to be structurally conformable on the Rewan Formation, but there is strong evidence that the formations are disconformable. In the Mount Carnarvon area the green lithic quartz sandstone of the Rewan Formation changes abruptly to white quartz sandstone of the Clematis Sandstone (S29, Pl. 9B). In Cona Creek several contacts were observed; interbedded reddish brown, green, and khaki silty shale, with a white leached zone, 1 to 2 feet thick at the top, is overlain by coarse granular thick-bedded cross-bedded quartz sandstone. The top of the Rewan Formation is also leached in the western half of the Sheet area. The sharp contacts and the presence of a leached zone at the top of the Rewan Formation suggest an erosional break, accompanied by a change in provenance and environment of deposition. South of Tanderra homestead, the Rewan Formation appears to be absent for a distance of about 15 miles (Pl. 6); this is probably due to local erosion of the Rewan Formation across the postulated northerly extension of the Nebine Ridge.

The Clematis Sandstone represents a marked change in provenance and depositional environment from the Rewan Formation. It is an extensive blanket quartz sand, which in the Baralaba Sheet area was derived mainly from the northwest (Olgers et al., 1966.). The abundance of cross-bedding and current ripple marks and minor scour structures suggests deposition by streams. The high quartz content and small amount of matrix are the result of fluviatile reworking. The interbedded siltstone and mudstone with abundant plant debris were deposited in isolated lagoons. The red-beds in the lower part of the formation indicate a temporary change to an environment similar to that in which the Rewan Formation was deposited.

The Clematis Sandstone is estimated to be about 800 feet thick in the west limb of the Rewan Syncline, of which 617 feet were measured (S29, Pl. 9B). In the west limb of the Early Storms Dome the formation is 405 feet thick (S28, Pl. 9B). The formation appears to thin to the west of the Serocold Anticline; in the western half of the Sheet it is probably only 200 feet thick.

The plants range from Triassic to Lower Jurassic (App. 3), and the spores indicate a Triassic age (Evans, 1966).

Moolayember Formation

The name Moolayember Shale was published by Reeves (1947). The name was revised to Moolayember Formation by Phillips (in Hill & Denmead, 1960). Whitehouse (1955) nominated the Injune-Rolleston road exposures on the descent to Moolayember Creek as the type section.

The formation crops out in the Rewan Syncline; in the west flank of the Serocold Anticline, beneath cliffs of Tertiary basalt and Precipice Sandstone; and in a belt about 10 miles wide, across the Springsure Shelf. It is poorly exposed and underlies areas of low relief in contrast to the cliffs formed by the Clematis and Precipice Sandstones; several resistant sandstone beds form low cuestas in the west. It supports a thin to dense cover of timber.

The formation consists predominantly of grey, greenish brown, and buff siltstone. Soft carbonaceous shale with thin beds of coal and peat and leaf beds are present (S28, Pl. 9B). Thin beds of reddish brown mudstone were observed in the Nogoa River near Cungelella homestead. A bed of fine even-grained quartzose sandstone occurs about 250 feet above the base of the Moolayember Formation in measured section S28. BMR No. 4 penetrated 200 feet of grey micaceous carbonaceous siltstone and interlaminated fine-grained sandstone and siltstone at the base of the formation (Arman, 1965a). The cuesta-forming sandstone is brown, friable, and fine to medium-grained; it is composed mainly of lithic, quartz, and abundant fresh angular feldspar grains, with a little biotite, muscovite, and iron oxide. It contains rounded calcareous concretions in places, and thin beds of carbonaceous, micaceous, calcareous sandstone, grading into sandy limestone, throughout. Whitehouse (1955) records oil shale at the top of the formation in the Nogoa River.

The Moolayember Formation is characteristically thin-bedded to laminate; ripple marks and worm-tracks are found in places, and mud clasts at the base. Cross-bedding is rare. At the top is a weathered and leached zone up to 10 feet thick. The shale is pink and ash-grey, and the sandstone is purplish and mottled.

The Moolayember Formation overlies the Clematis Sandstone with structural conformity. In the western part of the Sheet and in the Rewan Syncline the cross-bedded quartz sandstone of the Clematis Sandstone grades into the feldspatholithic sandstone of the Moolayember Formation; the boundary is taken at the top of highest bed of quartzose sandstone. In the west flank of the Serocold Anticline the boundary is sharp; in measured section S28 (Pl. 9B), the sharp break from cross-bedded quartzose sandstone to dark shale suggests a local hiatus.

There was a marked change in conditions of deposition between the Clematis Sandstone and the Moolayember Formation; the slow deposition of reworked quartz sandstone gave way to more rapid deposition of lutite and labile sandstone. The formation was deposited in a shallow non-marine basin. The mud clasts in the base of sandstone beds were probably formed by desiccation during periods of emergence, and were subsequently incorporated in the sand bodies.

The thickness of the Moolayember Formation varies greatly in the west flank of the Serocold Anticline because of angular unconformity at the base of the overlying Precipice Sandstone, which rests on the Clematis Sandstone in places (Pl. 6, 7B). Hill (1957) records a maximum thickness in the Springsure Sheet area of 1400 feet in Consuelo Creek. The basal 360 feet were measured in a creek south of Carnarvon Creek (S28, Pl. 9B). Information from waterbores indicates that the unit is at least 1000 feet thick in the western part of the Sheet area.

The plant fossils collected from the Moolayember Formation during the present survey are listed in Appendix 3. The palynological evidence indicates a Triassic age, not older than Middle Triassic (Evans, 1966).

CORRELATIONS OF PERMIAN AND TRIASSIC UNITS AND PALAEOGEOGRAPHIC INFERENCES

Correlations of the Permian units in the Springsure Shelf and the Springsure and Serocold Anticlines are shown in Plate 6 and Figure 2. The correlations are based on palaeontological and lithological data, mainly from outcrop.

Correlations of the Permian and Triassic units in the 19 exploratory wells east and south of the Springsure and Serocold Anticlines are shown in Plates 8A and 8B. The correlations are based on the lithological and electric well logs and the palaeontological evidence.

The mapping of the Springsure and Serocold Anticlines (Pls 7A, 7B) outside the area and the well logs from other Sheets give a broader picture of the regional tectonics and sedimentational history during Permian and Triassic times.

Reids Dome Beds and Orion Formation

Beds previously termed the 'lower shales and sandstones' and the 'undivided freshwater beds' by Webb (1956) are now included in the Reids Dome Beds as found in AOE No. 1 (Reids Dome). The Orion Formation in the Springsure Anticline is regarded as equivalent to the top 200 feet of the Reids Dome Beds. The Orion Formation is similar in lithology to the Reids Dome Beds and shows a transition to the overlying marine Stanleigh Formation (Fig. 7) similar to the transition of the Reids Dome Beds into the Cattle Creek Formation (as in AOE Nos 1 and 2 (Reids Dome)); the Stanleigh and Cattle Creek Formations contain similar marine faunas (App. 1).

On the Springsure Shelf there is a thin lenticular unit of non-marine sandstone and siltstone with a rich Glossopteris-Gangamopteris flora between the Joe Joe Formation and Colinlea Sandstone. The unit is almost certainly equivalent to part of the Reids Dome Beds.

Seven of the wells shown in Plates 8A and 8B have penetrated the Reids Dome Beds without reaching the base of the unit; the thickest section is 7365 feet in AOE No. 1 (Reids Dome). A complete section of about 1500 feet of the unit was penetrated in AAO Glentulloch No. 1. The basal sediments penetrated in Planet Warrinilla North No. 1 and AFO Inderi No. 1 are possibly Reids Dome Beds. The conglomeratic beds near the base of these wells, which contain mainly acid volcanic pebbles, may correspond to similar beds with acid volcanic pebbles in the Orion Formation near Dilly. The unit is absent in AAO Killoran No. 1, SQD No. 1 (Morella), AFO Purbrook No. 1, Marathon-Continental Glenhaughton No. 1, and Planet's Tooloombilla No. 1, Crystalbrook No. 1, and Warrong

No. 1. The volcanic rocks penetrated in the bottom of the Glenhaughton well possibly represent the Lower Permian Camboon Andesite, which is apparently equivalent to the Reids Dome Beds. The andesite of unknown age in the Morella well is a local equivalent of the Reids Dome Beds or, more probably, part of the land surface on which they were laid down (the postulated 'Morella High' of Webb (1956)).

The scanty data available suggest that the Reids Dome Beds were deposited in an asymmetric non-marine trough (Denison Trough) with a north-south elongation. The axis of downwarping was probably closer to the western margin of the trough, which was probably formed by a normal fault extending from slightly west of the Glentulloch well to west of Reids Dome. Possibly, therefore, the thick conglomerate in the Glentulloch well is of syntectonic origin. The configuration of the eastern part of the trough is less certain, but the boundary lay between the Purbrook and Rolleston wells; the thick conglomerate in the Rolleston well is probably related to the eastern margin of the trough. The 'Morella High' is probably an intrabasinal ridge or spur. The volcanic rocks in the Glenhaughton well and the Reids Dome Beds are possibly equivalent, and the volcanic province was probably separated from the Denison Trough by the Comet Ridge between the Arcadia and Glenhaughton wells; this is supported by the absence of the Reids Dome Beds in the Purbrook well. Alternatively, the two rock types interfinger in this area.

Cattle Creek Formation, Stanleigh Formation, Staircase Sandstone, and Sirius Formation

The Cattle Creek Formation is probably equivalent to the interval between the base of the Stanleigh Formation and the top of the Sirius Formation. The correlation was originally suggested by Patterson (1955) and Webb (1956). It was challenged by Mollan et al. (1964), who suggested that the Cattle Creek Formation was equivalent only to the Stanleigh Formation. More detailed mapping, petrological work, and subsurface correlation (Pls 8A, 8B) have shown that the alternative correlation is unlikely. The explanation now accepted fits the palaeontological data. The Staircase Sandstone appears to pass laterally into an interbedded shale-sandstone sequence to the north and south of the type area (Pl. 9A). Thin sandy representatives of the Staircase Sandstone are probably present in Inderi No. 1, Arcturus No. 1, and Reids Dome Nos 1 and 2 (Pl. 8A).

The Cattle Creek Formation is present in most of the wells shown in Plates 8A and 8B; the interval represents the basal Permian unit in Purbrook No. 1 and possibly Morella No. 1; the interval is about 2500 feet thick in the type areas of the Stanleigh Formation, Staircase Sandstone, and Sirius Formation, and in the Rolleston No. 1 and Consuelo wells. In all other wells it appears to be thinner; it wedges out to the west between the Bandanna and Warrong wells, to the south between Westgrove No. 1 and probably Kildare No. 1, and probably to the east between the Arcadia and Glenhaughton wells. The Lower Permian trough became open to the sea in Cattle Creek time. The trough was certainly broader than in Reids Dome Beds time, and the main north-south axis had migrated to the east. The sea transgressed the eastern flank of the old non-marine trough, and the postulated pre-Permian spur at the Morella well. If the Staircase Sandstone in the type area is a deltaic sand, the western shoreline in Cattle Creek time was probably close to its earlier position (i.e. immediately west of the Springsure and Serocold Anticlines). However, the wedging out of the Cattle Creek interval is related, in part at least, to a period of movement and erosion prior to Upper Permian sedimentation.

Aldebaran Sandstone, Ingelara Formation, Catherine Sandstone, and Colinlea Sandstone

The Colinlea Sandstone almost certainly represents the interval from the base of the middle conglomerate member of the Aldebaran Sandstone to the top of the Catherine Sandstone. The lower part of the Colinlea Sandstone is lithologically similar to the middle conglomerate member of the Aldebaran Sandstone. Bastian (1965a) has shown that there is a distinct lithological break near the top of the Colinlea Sandstone, where a complete section has been studied (section S6B, Fig. 6); the upper part shows lithological similarities to the Catherine Sandstone. Evans (pers. comm.) has identified an assemblage of spores from the Colinlea Sandstone in BMR No. 6 similar to that in the upper part of the Aldebaran Sandstone in Reids Dome. The Peawaddy Formation, overlying the Colinlea Sandstone, contains only the Mantuan Productus Bed fauna; no assemblages were found in the Peawaddy Formation that could be related to the fauna of the Ingelara Formation (App. 1).

The Colinlea Sandstone thickens eastwards, and it is possible that a representative of the Ingelara Formation is present in the east under the Tertiary basalt.

The correlation of the Colinlea Sandstone implies that the regional unconformity with the Reids Dome Beds in the Springsure Shelf is equivalent at least to the deposition of the lower sandstone member of the Aldebaran Sandstone and the Cattle Creek Formation in the Denison Trough.

The Aldebaran Sandstone/Ingelara Formation/Catherine Sandstone interval shows a similar relative thickness in the wells to the Cattle Creek Formation interval; there is apparently no major break in deposition between the four units. The three formations wedge out in turn to the south, east, and southwest of the Springsure and Serocold Anticlines; the Catherine Sandstone wedges out at the surface at the southern end of Reids Dome. The wedging out of the units beneath the Peawaddy Formation apparently represents a period of emergence, accompanied by gentle folding in the southern and eastern parts of the Denison Trough. Epeirogenic movement marks the end of Lower Permian sedimentation; it was followed by a transgressive phase of marine sedimentation in a basin with an axis of downwarp to the east of the Denison Trough.

Evidence supporting this interpretation has accumulated from several sources:

(i) The significance of the wedging out of the Catherine Sandstone is related to erosion and an unconformity of increasing overlap southwards and eastwards (see p.36).

(ii) Upper Permian sediments containing the clarkei-bed, which is probably the same age as the Mantuan Productus Bed (Dickins et al., 1964), overlap Lower Permian and older rocks on the western margin of the Bowen Basin in the Clermont Sheet area (Veevers et al., 1964b);

(iii) Subsurface interpretation (Pls 8A, 8B) supports an unconformable overlap at the base of the Peawaddy Formation east, south, and southwest of the outcrop area; the marine transgression in Peawaddy time is indicated by the presence of the Peawaddy Formation as the oldest Permian unit in some wells (e.g. Warrong No. 1).

Cundill, Meyers, & Associates (1963, 1965) and Power (1966) have interpreted the data in a different way. From an interpretation of well logs, Power has suggested a major regional unconformity at the base of the upper transition member of the Aldebaran Sandstone (i.e. Power's Freitag Formation, see Table 3). Power also contends that the Ingelara Formation/Catherine Sandstone/Peawaddy Formation interval is a conformable sequence, and that the Catherine Sandstone represents a lenticular bar sand. The critical differences between our interpretation and that of Cundill & Meyers and Power occur between Rolleston No. 1 and Purbrook No. 1 and between Warrinilla North No. 1 and Warrinilla No. 1. Although macrofossils from Glentulloch No. 1 (see Completion Report) appear to support our interpretation, the palaeontological and palynological evidence is insufficient to resolve the problem; the macrofauna in the Ingelara Formation is readily distinguished from that in the Peawaddy Formation (Mantuan Productus Bed) (App. 1), but insufficient specimens have been obtained from the wells to distinguish the assemblages. Similarly, the spore assemblages in the interval from the Aldebaran Sandstone to the Peawaddy Formation do not indicate the position of the break in deposition.

Peawaddy Formation and Black Alley Shale

The relationship of the Peawaddy Formation and the Black Alley Shale has been discussed on page 39 and summarized in Table 3. The identification of the Peawaddy Formation on the Springsure Shelf is based on lithology, the presence of the Mantuan Productus Bed at the top, and macrofossil horizons with affinities to the Mantuan Productus Bed within the unit. The Peawaddy Formation is fairly uniform in thickness in outcrop; it gradually thickens eastwards from the Springsure and Serocold Anticlines and the well logs suggest that it is thickest along the line of the Comet Ridge. The coal measure unit in the Inderi and Arcturus wells occurs in the Peawaddy Formation/ Black Alley Shale sequence.* The Mantuan Productus Bed cannot be identified in the wells; two correlations are present in Plate 8A assuming a pre-Mantuan age or a post-Mantuan age for the coal measures, which, from palynological evidence, do not belong to the Blackwater Group. If the coal measures are post-Mantuan, it is possible that they are absent in the south and that there is a disconformity at the top of the Peawaddy Formation as suggested.

The absence of the Mantuan Productus Bed in the southern exposed part of the Serocold Anticline is possibly related to local erosion. On the other hand, the coal measures indicate a gradual southerly regression of the sea, possibly in Peawaddy time, so that the peculiar marine transgression represented by the Mantuan Productus Bed possibly marks a temporary return to basinwide marine conditions.

The variation in thickness of the Black Alley Shale suggests that it was deposited in a basin the main axis of which was farther east than in Peawaddy Formation time, probably close to the present axis of the Mimosa Syncline, east of the Glenhaughton well. The Black Alley Shale is readily recognized by its characteristic lithology; it is present across the Springsure Shelf.

Blackwater Group

The stratigraphic relationships of the Blackwater Group in the Springsure Sheet area have been discussed on page 39. It is readily recognized in the wells by the presence of coals with a characteristic spore assemblage (Evans, 1964a, p. 4). The top of the group is taken as the top of the highest coal in most of the wells (see p. 00). The basal part is commonly marked by the presence of sandy beds. The group has a fairly uniform thickness (500-700 ft) throughout much of the region; it thins out to the west on to the Springsure Shelf as shown in the Warrong well (Pl. 8B). An apparent gradual thickening towards the axis of the Mimosa Syncline (Arcadia, Glenhoughton, and Purbrook wells) is a consequence of downwarping initiated in Peawaddy Formation time.

Rewan Formation, Clematis Sandstone, and Moolayember Formation

A few wells which penetrate the Triassic units show a rapid thickening of the sequence to the east and a rapid subsidence of the Bowen Basin along the axis of the Mimosa Syncline, east of the Glenhaughton well; the rate of subsidence in the depositional basin had increased since Black Alley Shale and Blackwater Group times. The thinning to the south is related to folding and erosion before the deposition of the Jurassic Precipice Sandstone. The apparent absence of Black Alley Shale and Blackwater Group equivalents in the Killoran well is possibly related to erosion before the Triassic Rewan Formation was laid down (the disconformity and gentle regional unconformity in the basal part of the Rewan Formation in the Early Storms Dome and Arcadia Anticline is possibly more marked to the south); the Blackwater Group appears to thin out rapidly under the Rewan

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* In Malone et al. (in press) the German Creek coal measures and Maria Formation (?) are identified in this part of the sequence. This does not affect the alternatives shown.

Formation between Kildare No. 1 and Glentulloch No. 1. The thinning of the Rewan Formation to the west is probably a combination of depositional thinning and minor erosion (the relationship with the Clematis Sandstone is apparently disconformable in outcrop).

Conclusions

The correlations and relationships suggested for the Permian and Triassic sequences offer a broad guide to the Permian and Triassic palaeogeographic evolution of the region; the palaeogeography is complex and the details require further investigation.

The Permian sequence fits well into the stratigraphic framework of other parts of the Bowen Basin (Malone, 1964). The threefold division of the Permian sequence into the Reids Dome Beds, Back Creek Group, and Blackwater Group is a natural separation expressing three distinct depositional regimes in the Permian evolution of the basin. The rapid downwarping of the Denison Trough with accompanying non-marine sedimentation along the western margin of the basin was possibly contemporaneous with the deposition of volcanic products along the eastern margin. The phase was followed by basinwide marine sedimentation, and a concluding phase of non-marine sedimentation. Palaeontological evidence shows that each of the three phases was essentially contemporaneous throughout the Bowen Basin; the second and final phases of deposition are characterized by similar lithological features throughout the basin.

Similarly, the marine Permian on the Springsure Sheet area can be related by broad lithological characteristics with a threefold division in other parts of the basin (Tiverton, Gebbie, and Blenheim Subgroups). The separation of the units of the Back Creek Group into subgroups is shown in Plate 6; palaeontological evidence shows that the lithological characteristics defining each of the subgroups are related to basinwide events. The data obtained during this survey have thus strengthened the conclusions of Dickins et al. (1964).

JURASSIC

The Jurassic units in the Springsure Sheet area are the Precipice Sandstone, Evergreen Formation (including Boxvale Sandstone and Westgrove Ironstone Members), Hutton Sandstone, and Birkhead Formation (Pl. 6). They were mapped with the aid of several helicopter traverses and by photogeological interpretation. The Jurassic sequence in the Eddystone Sheet area is described in Mollan et al. (1965a).

Precipice Sandstone

The name Precipice Sandstone was first used by Whitehouse (1953) for the lowest sandstone member of the Bundamba Group, in place of Bundamba Sandstone (Reeves, 1947). The type area and proposed type section are near Precipice Creek (Mollan et al., in prep.). Phillips (in Hill & Denmead, 1960) applied the name Morella Sandstone to the sandstone forming the cliffs to the south and west of Reids Dome. The sandstone can be traced into the type area and the name Morella Sandstone has been abandoned.

The Precipice Sandstone crops out in cliffs below the basalt tablelands west of Reids Dome, and forms sandy plateaux bordered by precipitous white cliffs in the southwest. Where the sandstone is exposed, the formation has a dark tone on the air-photographs due to the dense growth of small trees and bushes; where the sandstone is covered by deep residual sand, the vegetation is more sparse and the tone is lighter.

The Precipice Sandstone consists predominantly of medium to coarse-grained thickly cross-bedded quartz sandstone, with bands and lenses of pebble conglomerate; scattered cobbles are present. The pebbles and cobbles consist mainly of milky quartz and subordinate lithic sediments. Rare beds of fine-grained thin-bedded (occasionally festoon-bedded) micaceous quartz sandstone are present. The sandstone is friable and porous; a little kaolinite matrix is present in places. The sand grains are pressure-welded, with quartz overgrowths in places.

The Precipice Sandstone unconformably overlies the Moolayamber Formation and Clematis Sandstone in the west limb of Reids Dome. In the southwest it disconformably overlies leached or ferruginized sediments of the Moolayember Formation. The Precipice Sandstone has a low regional dip to the south and is folded into several small domes to the south and southwest of the headwaters of Meteor Creek. The domes are probably related to Tertiary igneous intrusions. The unit dips off the west flank of the Serocold Anticline; the dip of about 5^{o} at the eroded edge of the unit rapidly decreases to the west.

The Precipice Sandstone seems to have originated in an unusual set of conditions. Its wide extent and the almost total absence of argillaceous sediments are probably the result of much reworking of sediment by meandering streams in a slowly subsiding basin. A quartz-rich provenance, mature streams, and recurrent flooding in the basin probably combined to produce the blankets of clean sand. The orientation of the cross-bedding indicates a predominance of currents from the west and northwest.

The formation is about 500 feet thick in the west, and about 200 feet in the east.

Lower Jurassic spores are present in other areas (Evans, 1966).

Evergreen Formation, Boxvale Sandstone Member, and Westgrove Ironstone Member

Whitehouse first used (1953) and defined (1955) the name Evergreen Shales, after Evergreen homestead in the Taroom Sheet area. The name Evergreen Formation is being extended by Mollan et al. (in prep.) to include the sequence from the base of the Hutton Sandstone to the top of the Precipice Sandstone. The unit includes two lenticular members, the Boxvale Sandstone and Westgrove Ironstone Members.

The name Boxvale Sandstone, after Boxvale homestead in the Taroom Sheet area, was introduced by Reeves (1947), and the name Westgrove Ironstone Member, after Westgrove holding in the Taroom Sheet area, was introduced by Mollan et al. (1965a). The two units are overlain by shale, similar to shale below the Boxvale Sandstone, in the type area of the Evergreen Formation. Where the Boxvale Sandstone wedges out, the two shale sequences cannot be separated, so the Evergreen Formation was extended to cover both sequences. The Westgrove Ironstone Member overlies the Boxvale Sandstone Member and is associated with the upper shaly sequence of the Evergreen Formation. The shaly sequence is very thin in the Springsure Sheet area and has been included with the Westgrove Ironstone Member in Plate 6. Type sections of the Boxvale Sandstone and Westgrove Ironstone Members are present in Mollan et al. (1965a; & in prep.).

The Evergreen Formation (pre-Boxvale Sandstone) crops out in steep scree-covered slopes in the southeastern part of the Sheet area. The formation can be detected on the air-photographs by slope and tone breaks between the cliff-forming Boxvale Sandstone Member and Precipice Sandstone. The sequence is poorly exposed; on the Eddystone Sheet area to the south, the pre-Boxvale Sandstone Member part of the Evergreen Formation is represented by soft silty mudstone and minor lithic sandstone and coal (Mollan et al., in prep.). The formation wedges out to the west, and to the west of Marlong Creek it is either very thin or absent, and is represented only by the Boxvale Sandstone and Westgrove Ironstone Members.

The Boxvale Sandstone Member crops out across the southern part of the Springsure Sheet, mainly south of latitude 24°45' S. It forms benches in the slopes beneath the Tertiary basalt tablelands in the east, but to the west it crops out in mesas and buttes and in spectacular white cliffs around the head of the Nogoa River. The member consists of white quartzose sandstone which is typically fine, even-grained, and thin-bedded with low-angle cross-bedding; coarse pebbly quartzose sandstone beds are present, especially to the west. Beds of flaggy micaceous ripple-marked sandstone are present.

The Westgrove Ironstone Member crops out in small areas along the southern margins of the Sheet area. It has been identified by the presence of boulders of concretionary ironstone embedded in deep red soil covering the benches formed by the Boxvale Sandstone Member, and by extrapolation from the Eddystone Sheet area. It is characterized by oolitic and pelletal ironstone in the type area, but these structures have not been noted in the Springsure Sheet area. The member consists mainly of ferruginized argillaceous sediments.

The member is poorly developed or absent to the northwest of the Warrego River.

The Evergreen Formation is apparently conformable on the Precipice Sandstone. The pre-Boxvale Sandstone sequence interfingers with the quartz sandstone of the Boxvale Sandstone Member to the west; the Westgrove Ironstone Member probably has a similar relationship to the Boxvale Sandstone Member to the west.

The boundary between the Boxvale Sandstone Member and the Precipice Sandstone in the western half of the Sheet area is defined by a bench at the top of the Precipice Sandstone, which has a tough case-hardened skin, and is more resistant to erosion than the soft and friable Boxvale Sandstone. The Precipice Sandstone is typically massive and cross-bedded, whereas the Boxvale Sandstone is well bedded, and cross-bedding is less prominent; the Precipice Sandstone is mainly coarse-grained and commonly pebbly, whereas coarse pebbly beds only occur at intervals in the Boxvale Sandstone.

Evidence from outside the Sheet area (Mollan et al, 1965a; & in prep.) suggests that the pre-Boxvale Sandstone part of the Evergreen Formation was deposited in a shallow basin possibly with ephemeral marine incursions. The Boxvale Sandstone Member wedges out towards the centre of the Taroom Sheet area, and it probably represents an easterly regression in the basin. The low-angle cross-bedding probably indicates deposition on the margin of the basin; to the west, the sand is mainly of fluviatile origin. The Westgrove Ironstone Member was probably deposited in a shallow basin during a transgressive, possibly marine, phase. The western extent of the marine incursion is indicated by the lateral transitions of the pre-Boxvale Sandstone sequence and Westgrove Ironstone Member into the Boxvale Sandstone Member.

The Evergreen Formation is probably between 200 and 300 feet thick throughout the Springsure Sheet. Measured thicknesses to the south are present in Mollan et al. (1965a; & in prep.).

The Evergreen Formation contains Lower Jurassic spores and acritarchs above and below the Boxvale Sandstone Member (Evans, 1966). No fossils have been recorded in the Springsure Sheet area.

Hutton Sandstone

The name Hutton Sandstone was introduced by Reeves (1947). The type area is near Hutton Creek in the Eddystone and Taroom Sheet areas; a type section is given by Mollan et al. (1965a; & in prep.).

The formation extends from the type area through the Eddystone Sheet into the southern part of the Springsure Sheet. Small outcrops occur along the southeastern boundary of the Springsure Sheet area and there is a broad belt of outcrop in the southwest corner. The formation is poorly exposed because it readily breaks down to a residual sandy soil. It consists of poorly cemented quartzose sandstone with a significant proportion of feldspar and kaolin matrix in places. The poorly sorted sandstone is mainly thick-bedded; it is cross-bedded in places and contains rare beds with pebbles and mud clasts.

The Hutton Sandstone is apparently conformable on the Evergreen Formation, but the wedging out of the Westgrove Ironstone Member in the west suggests a disconformity.

The Hutton Sandstone was probably deposited in lacustrine and fluviatile environments. It represents a gradual transition from the possibly partly marine basin of Evergreen time to the non-marine paludal environment of the overlying Birkhead Formation.

The formation is probably between 300 and 400 feet thick in the Springsure Sheet area. Palynological evidence indicates a Lower to Middle Jurassic age (Evans, 1966).

Birkhead Formation

The name Birkhead Formation was introduced by Exon (1966) for the lowermost part of the Injune Creek Group (previously Injune Creek Beds) in the western part of the Eddystone Sheet area. There is a very small outcrop in the southwest corner of the Springsure Sheet area; it was mapped by air-photo interpretation and by extrapolation from the Eddystone Sheet area.

The formation consists of interbedded lithic sandstone, siltstone, and minor coal, and is probably conformable on the Hutton Sandstone. It was deposited in lacustrine and paludal environments. The top of the formation is not present in the Springsure Sheet area, and the thickness is probably only 100 feet. The Birkhead Formation contains Middle Jurassic spores (Evans, 1966).

TERTIARY

Flood Basalts and Pyroclastics

A dissected sheet of Tertiary basalt and less basic lavas covers much of the eastern half of the Springsure Sheet area; several small outliers also occur in the southwest quadrant. To the north, west, and east of Springsure, pyroclastic rocks and sediments are interbedded with the flows. The best outcrops are found along the edge of the basalt sheet.

The flows include olivine basalt and less basic, probably intermediate, lavas. The olivine basalt flows are hard and have well developed platy jointing, but the less basic rocks are generally scoriaceous and massive. The pyroclastics near Springsure generally consist of massive reddish purple scoriaceous agglomeratic tuffs, which are probably trachytic in composition, and well bedded off-white fine rhyolitic agglomerate and tuff. The lavas and pyroclastics north of Springsure are capped by a flow of the Minerva Hills Volcanics.

The flows were extruded from fissures which are now filled by dykes; swarms of basalt dykes, commonly trending north-south, and sills are exposed near the head of Orion Creek, and several were also observed near the southern end of Reids Dome. The dykes and sills intrude Permian sediments. The dykes intruding the Orion and Stanleigh Formations near the head of Orion Creek have baked the shales to a dark splintery rock; they have also contorted the bedding. The baked zones are commonly less than a foot wide. Several dykes intrude the Tertiary flows, particularly in the Sandy Creek/Meteor Creek area, west of the Springsure Anticline.

Flows were also extruded from vents: the basalt plugs form conical hills, but most of the flows have been denuded.

The pyroclastics, and probably some of the lavas, to the west, north, and east of Springsure were probably extruded from vents and fissures in the area now occupied by the Minerva Hills Volcanics. At least three beds of rhyolitic agglomerate and tuff have been identified in the volcanic pile; they possibly represent intrusions of acidic lava of the Minerva Hills Volcanics type, shattered and pulverized by explosive activity at the onset of a new phase of vulcanicity.

The basaltic sheet probably covered much of the Sheet area, except the northwest quadrant. The lavas were extruded on to an uneven terrain: the base of the basalt sheet is about 700 feet above sea level east of the Springsure Anticline, but west of Springsure the base of the sheet is over 1000 feet above sea level, and at Mount Serocold in the southeast it is about 2500 feet above sea level.

Lava was extruded to the west of the range formed by the Springsure Anticline and Reids Dome. Some of the lava breached the barrier and flowed down the streams to the east, and tongues of basalt are still preserved in the valleys in the Permian rocks across the Springsure Anticline (see Pl. 6).

Near Springsure, the flows dip away from the Dilly Pinnacle/St Peter/Red Hill triangle, and to the north of the Great Dividing Range they dip gently to the north.

Between Springsure and the top of Mount Boorambool the volcanic pile is 900 feet thick, and a similar thickness is probably present in the Buckland Tableland. Elsewhere the sheet is much thinner and has been partly removed by erosion.

The basalt lavas overlie the Lower Jurassic Precipice Sandstone. Dating by the K/Ar method indicates an Oligocene age (A.W. Webb, App. 7).

Minerva Hills Volcanics

The Minerva Hills Volcanics were named by Veevers et al. (1964a) after Minerva Hills homestead in the Emerald Sheet area, about a mile north of St Peter. The volcanics occur in the Minerva Hills, a group of sharp rocky peaks, ridges, and mesas west of the Emerald-Springsure road near the boundary between the Emerald and Springsure Sheet areas.

Four protrusions of the Minerva Hills Volcanics in the Great Dividing Range, near the heads of Meteor, Skeleton, and Sunday Creeks, were visited by helicopter in 1964 (Pl. 6).

The Minerva Hills Volcanics consist of a suite of alkaline rocks ranging from trachyte to alkaline rhyolite. They are preserved mainly as dykes, plugs, and domes; a dissected flow or series of flows is also present. The protrusions form rocky peaks and ridges, of which the most prominent are St Peter, Red Hill, and Dilly Pinnacle; most of the other protrusions occur in the triangle between these peaks. The dissected flow or flows and domes form a rocky undulating plateau to the south of the protrusions, and extend southwards to Mount Zamia near Springsure. There are several small outliers of the flow to the west of the plateau.

The dykes form rocky ridges and vary greatly in length and width; their size is difficult to determine because of the complex mode of intrusion. Several dykes, radiating from a central plug about a mile south of Red Hill, are over half a mile long and about 10 feet wide, but most of them are shorter and wider. They are generally nearly vertical and trend mainly northwest. Jointing normal to the walls is common. Autobrecciation is common on the edges, and some are closely sheared and brecciated. Along the line between Dilly Pinnacle and St Peter there is a complex of multiple auto-intrusive dykes with local centres marked by plugs (Pl. 5, fig. 2).

The plugs are commonly roughly circular in plan, but those associated with multiple dyke complexes are more irregular. St Peter, the largest plug, is roughly elliptical in plan. It is about half a mile long, and nearly 1000 feet high; it has sheer flanks and a flat summit. In places, the plug displays crude columnar jointing. The spacing of the joints ranges from several inches to about 5 feet. The widely spaced joints are the more persistent and generally normal to the flanks; several sets of joints at about 1-foot spacing are roughly parallel to the flanks. Autobreccia is common around the base of the plug. Some of the smaller plugs are only about a hundred yards wide, such as the needle-like plug a mile southeast of St Peter. The jointing and shearing are similar to those in St Peter. Flow banding is common in some of the plugs; it is generally vertical and parallel to the walls of plugs. The domes are broader in plan and have more sloping sides than the plugs. They were extruded as domed masses of lavas over vents, with some lateral displacement of lava from the vent, whereas the plugs represent exhumed volcanic necks.

Red Hill is a dome with a marked depression in the centre. It is roughly circular in plan, and is about half a mile across; the joint pattern and peripheral autobreccia are similar to those in the plugs. The depression was probably caused by the retraction of lava from above the vent.

The flow or flows forming the plateau to the south of the intrusions have an uneven rocky surface, and the hummocks probably represent domes. The flows rest on basaltic flows and form a hard capping from 50 to 200 feet thick at the exposed edge.

The Minerva Hills Volcanics are light grey to off-white, fine-grained, and commonly porphyritic; flow banding is common. The composition ranges from trachyte to comendite. They contain phenocrysts of anorthoclase and minor sanidine, quartz, and a little sodic pyroxene, sodic amphibole, and magnetite. Porphyritic green pitchstone is common on the margins of intrusions. The volcanics have been hydrothermally altered. Detailed description of the Minerva Hills Volcanics in the Emerald Sheet area are given in Veevers et al. (1964a).

The Minerva Hills Volcanics were erupted, probably subaerially, from fissures and vents. The acid magma appears to have been intruded along northwest-trending basement rifts (Pl. 5, fig. 2). The intrusions have domed and pierced the Lower Permian Orion and Stanleigh Formations and the Staircase Sandstone, but no contact metamorphism is evident.

The small domes in Lower Jurassic rocks near the protrusions in the Great Dividing Range probably represent buried intrusions associated with the Tertiary vulcanism. The breached dome 4 miles southwest of Mount Sugarloaf is pierced near the centre by a small protrusion; it is probably associated with a cupola of acid magma.

The Minerva Hills Volcanics and the unnamed basalt flows are almost certainly comagmatic: the acid magma was probably a differentiate of the basaltic magma. They are similar to the volcanics in the Peak Range on the Clermont Sheet area and probably belong to the same volcanic province (see Mollan, 1965).

The Minerva Hills Volcanics protrude through the Lower Jurassic rocks and the well preserved form of the extrusions suggests that they are much younger than Jurassic. Sanidine phenocrysts from a quartz trachyte intrusion at Crystal Hill in the Emerald Sheet area have been dated as Oligocene to Miocene by the K/Ar method (A.W. Webb, App. 7).

Collapsed Basalt Sheets

In the rugged densely timbered foothills on the northern side of the basalt tablelands, between Freitag Creek and Tanderra homestead, the Tertiary basalt sheets have collapsed to form prominent knife-edge ridges and hummocky terrain. The collapsed basalt has a distinctive dark tone on the air-photographs and the ridges show as distinct lines. The collapsed sheets overlie the soft Black Alley Shale, Blackwater Group, and Rewan Formation, which have been eroded away and so undermined the basalt. The basalts overlying the more resistant Clematis Sandstone, Moolayember Formation, and Precipice Sandstone have not collapsed.

In small tributaries of Cona Creek, about a mile south of Goathland homestead, brecciated basalt was observed at creek level in trenches cut in the Blackwater Group whereas farther south, the basalt rests on Clematis Sandstone, several hundred feet above the creeks.

Tertiary Sediments

Small outliers, on basalt, of the extensive sheet of Tertiary sediment found to the east and northeast crop out along the eastern margin of the Sheet area; and inliers under and within basalt in the northeastern corner. Outcrops in mesas about 5 miles west of Springsure and 2 miles west of Mount Zamia of sediments interbedded with basalt are too small to be shown on Plate 6.

The sediments are flat-lying sandstone, pebbly conglomerate, and poorly exposed clays. The outcrop about 5 miles west of Springsure, in the cuttings along the Central-Western Highway, consists of a soft massive light clay which is possibly diatomaceous; at the contact with an overlying basalt flow or sill it is baked to a black brittle rock. About a mile west of Mount Zamia a fairly hard cross-bedded pebbly sandstone is interbedded with the lavas. In the northeast corner, the sediments have been deeply weathered into unconsolidated gravel, sand, and clay.

The coarse sediments are probably fluviatile deposits, and the clays were probably deposited in lakes formed by the damming of the streams by lava flows. The thickness of the sediments is variable. They are regarded as Tertiary because of their close association with the Tertiary lavas.

Laterite

Three lateritized mesas about 200 feet high are preserved in the far northwest. The laterite has an upper red zone and a lower white zone with boulders of silcrete at the base. It has formed on sediments of the Joe Joe Formation.

The Permian Catherine Sandstone and Peawaddy Formation are lateritized on the west flank of the Springsure Anticline; the profiles are well exposed. The laterite is overlain by basalt, possibly of Oligocene age.

A small outcrop of Tertiary sediments, to the east of the Rewan Syncline, has a thin capping of laterite.

CAINOZOIC

Sediments and Soils

Several superficial sediments are grouped under the symbol Cz on Plate 6. Rounded pebble and cobble gravels with scattered boulders crop out on the Nogoa and Telemon Anticlines. The fragments are strongly silicified. Much of the gravel has probably been derived from conglomerates in the Joe Joe Formation. Thick deposits of scree, composed of cobbles and boulders of basalt and silcrete, occur around the borders of the Tertiary basalt tablelands. A fine-grained siliceous rock occurs in places at the top of the Clematis and Colinlea Sandstones where they are in contact with basalt, and the boulders of silcrete were probably derived from these zones.

Residual sandy soil covers large areas of the Colinlea, Precipice, Boxvale, and Hutton Sandstones. Residual heavy dark soil covers much of the Tertiary basalt and the Black Alley Shale, Blackwater Group, and Rewan and Moolayember Formations.

Alluvium

Thick alluvium is confined mainly to narrow belts along most of the rivers and large creeks. In places, wide belts of thick alluvium occur along the Nogoa River, and the Vandyke, Freitag, Orion, Meteor, Consuelo, and Carnarvon Creeks.

STRUCTURE

Nebine Ridge

The Nebine Ridge is a major, mainly buried, feature which extends from the Eulo Shelf in southern Queensland to the Anakie Inlier, north of the Sheet area. The ridge, first recognized by Hill (1951), is exposed in three inliers (mainly gabbro in Asbestos Gully, Eddystone Sheet area; and metamorphosed sediments and granite in the Telemon Anticline, and in the Anakie Inlier, Clermont Sheet area) which indicate a complex internal structure. Isotopic dating of the gabbro and metamorphics and granite from the Telemon Anticline (App. 7) indicates a probable Lower Palaeozoic age for the Nebine Ridge.

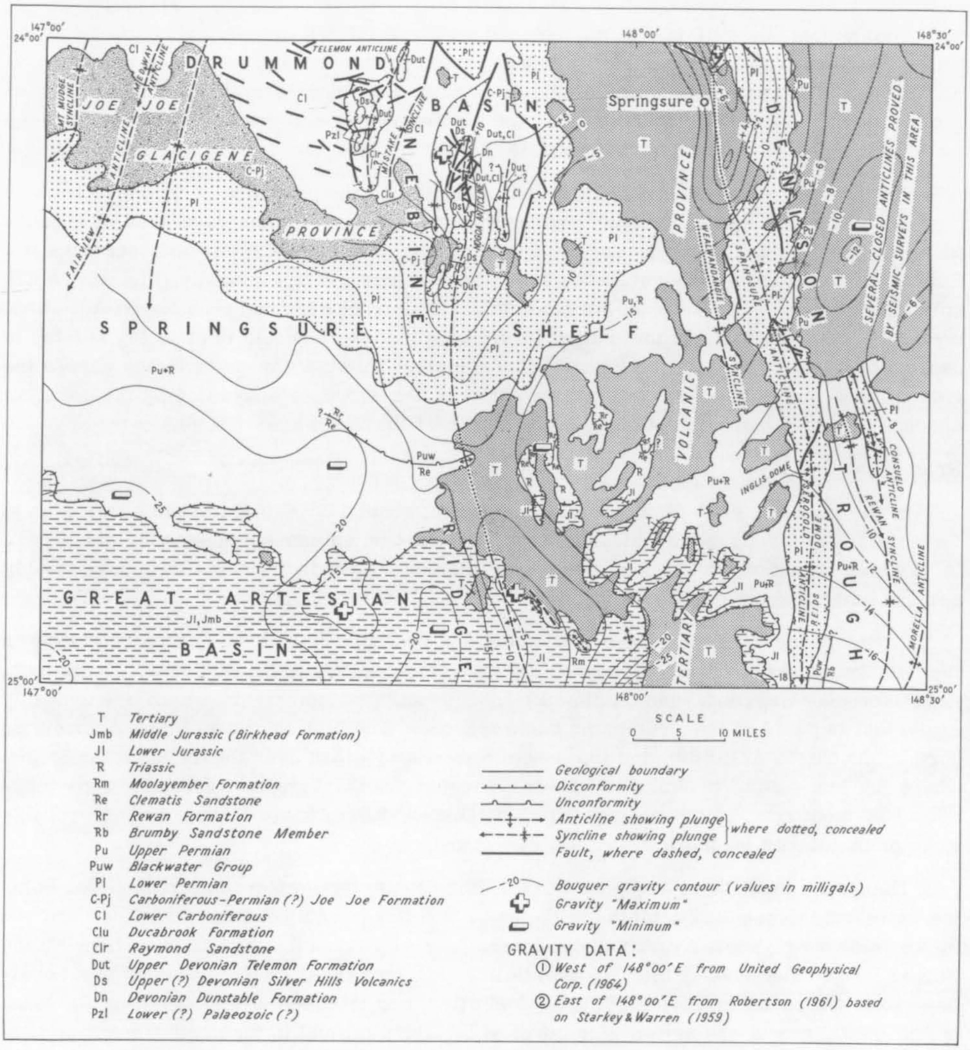
Geophysical surveys and drilling have established the presence of the ridge beneath the Great Artesian Basin Jurassic-Cretaceous sequence south of the Sheet area. The ridge formed an intrabasin swell during the Jurassic and Cretaceous, and separates the Eromanga Basin from the Surat Basin. A positive Bouguer gravity anomaly (Fig. 10), which coincides with a broad fold in Permian to Jurassic rocks and with the Nogoa Anticline, confirms the position of the ridge in the Sheet area. The fold is probably related to depositional draping. Also, the Evergreen Formation shows a change in facies across the ridge. Post-Palaeozoic tectonic rejuvenation of the ridge is suggested by the apparent absence of the Rewan Formation near the centre of the Sheet area (Pl. 6).

Drummond Basin

In the exposed part of the Drummond Basin, about 14,500 feet of Upper Devonian to Lower Carboniferous sediments and volcanics rest on an uneven basement floor. There is one major unconformity and one major disconformity in the sequence, and probably several other disconformities.

Little is known of the subsurface extent and configuration of the Drummond Basin in the Springsure Sheet area. To the south and west, exploratory wells (Killoran, Glentulloch, Crystalbrook, Warrong, and Purbrook) have penetrated sediments which are probably equivalent to parts of the Drummond Basin sequence. The high magnetic intensity over the core of the Nogoa Anticline, and the lack of a similar feature over the Telemon Anticline, where the Dunstable Volcanics are absent, suggest that the Volcanics form strongly magnetic basement (Fig. 11). The Silver Hills Volcanics and the Anakie Metamorphics probably form much weaker magnetic basement elsewhere.

The Drummond Basin sequence was folded, probably during Carboniferous time. Folding is more intense and complex in the east. The Nogoa and Telemon Anticlines are two major folds which appear to have been controlled by local north-south culminations on the Nebine Ridge. The core of the Nogoa Anticline is complicated by the presence of a horst-like block of Dunstable Volcanics, unconformities, and intense faulting (see Fig. 3). Much of the east limb of the anticline is covered by alluvium; and to the south the anticline is covered by the overlapping Colinlea Sandstone. The west limb is well defined; the steep westerly dip is interrupted by a small flexure (see section ABC in Pl. 6) which merges into a well defined south-plunging syncline to the south. The east limb is poorly defined; it is complicated by faulting, and by the presence on the east flank of the Vandyke Anticline - a south-plunging structure with steeply dipping to vertical strata. The Nogoa Anticline plunges to the north; the southerly plunge cannot be confirmed because of overlapping Colinlea Sandstone. The northerly plunge is complicated by a longitudinal fault downthrown to the east, which brings the Ducabrook Formation(?) in contact with Telemon Formation. Most of the faults in the Nogoa Anticline are normal.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DRUMMOND BASIN
JOE JOE GLACIGENE PROVINCE
SPRINGSURE SHELF
NEBINE RIDGE
GREAT ARTESIAN BASIN
VOLCANIC PROVINCE
DENISON TROUGH
TERTIARY
Springsure
TELEMON ANTICLINE
MT MUDGE SYNCLINE
MIDWAY ANTICLINE
FAIRVIEW ANTICLINE
MISTAKE SYNCLINE
MOOGA ANTICLINE
WEALWANDANGIE SYNCLINE
SPRINGSURE ANTICLINE
INGLIS DOME
REIDS DOME ANTICLINE
CONSUELO ANTICLINE
REWAN SYNCLINE
MORELLA ANTICLINE
SEVERAL CLOSED ANTICLINES PROVED BY SEISMIC SURVEYS IN THIS AREA
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C-Pj
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Clu
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Dut
Ds
Dn
Pzl
Tertiary
Middle Jurassic (Birkhead Formation)
Lower Jurassic
Triassic
Moolayember Formation
Clematis Sandstone
Rewan Formation
Brumby Sandstone Member
Upper Permian
Blackwater Group
Lower Permian
Carboniferous-Permian (?) Joe Joe Formation
Lower Carboniferous
Ducabrook Formation
Raymond Sandstone
Upper Devonian Telemon Formation
Upper (?) Devonian Silver Hills Volcanics
Devonian Dunstable Formation
Lower (?) Palaeozoic (?)
SCALE
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Geological boundary
Disconformity
Unconformity
Anticline showing plunge
Syncline showing plunge
where dotted, concealed
Fault, where dashed, concealed
20
Bouguer gravity contour (values in milligals)
Gravity "Maximum"
Gravity "Minimum"
GRAVITY DATA:
① West of 148°00′E from United Geophysical Corp. (1964)
② East of 148°00′E from Robertson (1961) based on Starkey & Warren (1959)

Figure 10

The Telemon Anticline is a long, slightly sinuous, asymmetrical dome with a steeper easterly limb. It is complicated by the presence of a basement inlier and a set of mainly transverse normal faults. The anticline is well defined by the cuestas and scarps of the Mount Hall Conglomerate and Raymond Sandstone.

The southern plunge of the broad Medway Anticline in the Ducabrook Formation lies west of the Telemon Anticline.

Joe Joe Glacigene Province

The terrestrial glacigene sediments of the Joe Joe Formation are broadly warped about folds in the Drummond Basin sequence. The unconformity at the base of the formation is less marked in synclines, where depositional and compactional dips tend to obscure the relationship. The thinning out of the Joe Joe Formation to the east is probably due mainly to Lower Permian erosion and overlap at the base of the Colinlea Sandstone.

Denison Trough

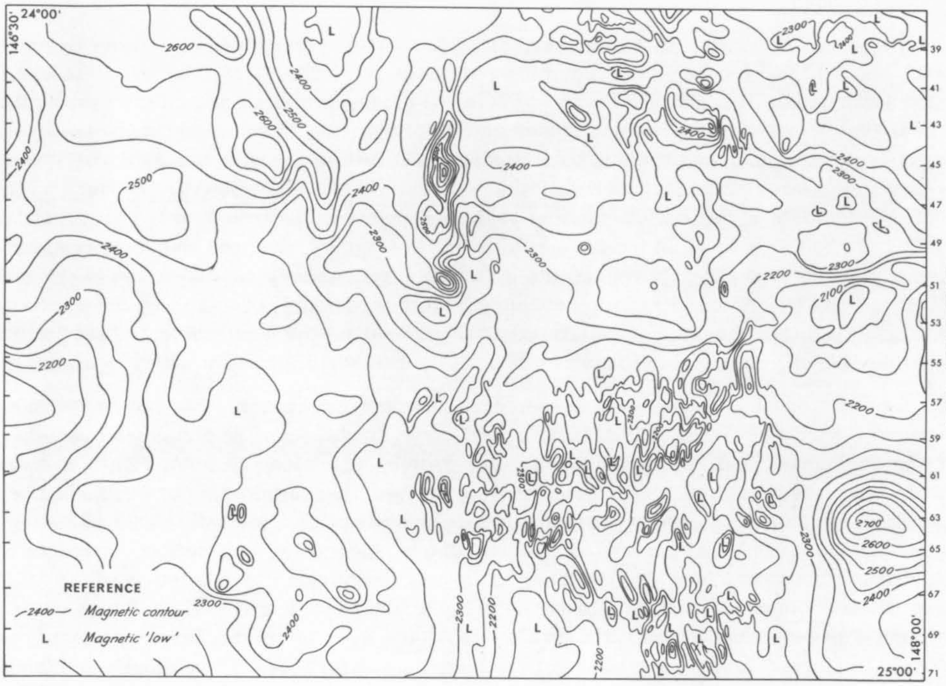
The Denison Trough is a downwarp along the western margin of the Bowen Basin in which about 12,000 feet of Lower Permian sediments were deposited. The trough is elongated north-south; it is bounded on the west by the Springsure Shelf and on the east by the Comet Platform beyond the Sheet area (see Pls 8A, 8B). Litttle is known about the basement to the Lower Permian sequence in the trough; the andesite in the SQD No. 1 (Morella) well is possibly a pre-Permian basement spur ('Morella High' of Webb (1956)). The gravity contours indicate a regional thickening of the sediments in the trough to the south, and a north-northeasterly trend in the trough to the north (Fig. 10). The positive gravity anomaly near Springsure possibly represents a Tertiary igneous body related to the basalt and Minerva Hills Volcanics. Magnetic basement features are mainly obscured by the Tertiary basalt; a positive magnetic anomaly of 2700 gammas at the northern end of the Rewan Syncline is an outstanding feature (Fig. 11), the significance of which is unknown.

Several unconformities and disconformities are present in the Lower Permian sequence, which has been folded into several large structures. The structure consisting of the Springsure and Serocold Anticlines is over 90 miles long (Pls 7A, 7B); both anticlines are asymmetrical, with steeper west limbs. The culmination of the Springsure Anticline, which is obscured by Tertiary basalt, probably lies a few miles east of Springsure. The east limb and the northern and southern plunges are well defined by ridges of Aldebaran Sandstone. The long northerly plunge is complicated by intrusions of the Minerva Hills Volcanics, and by thrust faulting to the west. A major fault, which passes through Fernlees, has produced a small subsidiary syncline in the Emerald Sheet area (Pl. 7A). Thrust faults are also exposed on the western flank of the gentle southerly plunge of the Springsure Anticline.

The Serocold Anticline consists of four culminations: Inglis Dome and Reids Dome in the Springsure Sheet area, and Early Storms and Bandanna Domes in the Eddystone Sheet area (Pl. 7B). Reids Dome, the largest of these structures, is particularly well defined by cuestas and scarps of Aldebaran Sandstone.

The Consuelo Anticline, which is an elongated asymmetrical dome, with a steeper west limb, and the Morella Anticline are the only other exposed anticlines in the Denison Trough. Several domes and anticlines concealed by Tertiary basalt are indicated by the contours on the Permian seismic reflectors in the northeast (Fig. 12); the folds have an en echelon arrangement.

A very gentle east-west flexure is present at the northern end of Reids Dome; the fold forms a slight saddle on the Rewan Syncline. The presence of a zone of high magnetic intensity (Fig. 11) suggests that the cross-fold is possibly related to a basement ridge, similar to the 'Morella High' (Webb, 1956).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REFERENCE
2400 Magnetic contour
L Magnetic 'low'

Figure 11

The Springsure-Serocold Anticline was formed by compression of a thick sedimentary pile; a force from the east is indicated by the asymmetry of the folds, which have steeper west limbs, and by thrusting to the west. The thrust faults are related to rejuvenation of a major crustal weakness which initiated the Denison Trough with normal faulting down to the east. The thick early Permian sedimentation close to the western margin of the trough indicates rapid subsidence adjacent to the major fault.

Springsure Shelf

The Springsure Shelf is a Lower Permian depositional platform of pre-Permian rocks bordering the Denison Trough. Deposition was slow, intermittent, and mainly fluviatile. The broad gentle folds in the Lower Permian rocks are imposed on a regional dip to the south; several of the folds coincide with folds in the Drummond Basin sequence. The fault scarps bounding the Colinlea Sandstone to the east and north of the Nogoa Anticline probably represent post-Permian rejuvenation of pre-Permian faults in the Drummond Basin.

Upper Permian to Triassic Basin

The Lower Permian Denison Trough and Springsure Shelf were replaced in the Upper Permian by a broad basin with its main axis to the east of the Springsure Sheet area. Four thousand five hundred feet of Upper Permian to Triassic sediments accumulated in the basin; they rest disconformably on the Lower Permian sequence, but in the east and south they are unconformable. The sequence contains several disconformities which are locally prominent, and has been infolded with the Lower Permian sequence.

Great Artesian Basin

A sheet of Lower to Middle Jurassic mainly fluviatile sediments rests unconformably on the Triassic sequence in the east, and disconformably on the Triassic Moolayember Formation in the west. The sheet has a regional dip to the south with several gentle undulations about folds in pre-Jurassic rocks. The sediments dip to the west at about 5^{o} off the west flank of Reids Dome; the dips here are probably partly depositional and partly due to compaction.

The four small circular domes, with dips up to 10^{o}, near the head of Marlong Creek are probably associated with concealed Tertiary intrusions; a small plug of Minerva Hills Volcanics protrudes through Moolayember Formation(?) exposed in one of the domes (Pl. 6).

Tertiary Volcanic Province

A sheet of Tertiary flood basalts, up to 1000 feet thick, rests unconformably and disconformably on Devonian to Jurassic rocks. Basalt plugs, dykes, and sills are associated with faulting and folding, especially in the Springsure and Serocold Anticlines. The Minerva Hills Volcanics have domed the Permian and Triassic sediments. A northwest-trending suite of dykes and plugs of the Minerva Hills Volcanics, several miles north of Springsure, is related to a major basement fault which controlled the extrusion of the Tertiary lavas (Pl. 5, fig. 2); the Permian sediments have been steeply tilted along the fault. The positive Bouguer gravity anomaly of 8 milligals to the north of Springsure is probably related to a concealed intrusion associated with the Tertiary basalt and Minerva Hills Volcanics (Fig. 10).

GEOLOGICAL HISTORY

The Anakie Metamorphics were probably formed by metamorphism and granitic intrusion of a sequence of sediments and igneous rocks in the Lower Palaeozoic. The metamorphics formed a ridge (Nebine Ridge), and the granite stock exposed in the Telemon Anticline probably formed a local culmination. During the early part of the Devonian, or possibly in the late Silurian, andesitic lavas and pyroclastics (Dunstable Volcanics) were deposited across the Nebine Ridge, at least in the area of the Nogoa Anticline. The ridge was inundated by the sea, and coral reefs formed in early Middle Devonian time.

A period of faulting and folding, probably in the upper part of the Middle Devonian, resulted in the formation of a broad downwarp with an irregular floor (Drummond Basin). Acid to basic lavas were deposited in the basin during the Upper Devonian. Periods of volcanic eruption alternated with sedimentation in the Nogoa Anticline area; the sediments were probably derived from the Nogoa Ridge and were deposited on its flanks. The deposition of the Silver Hills Volcanics was followed by epeirogenic movement and rejuvenation of established faults, especially in the Nogoa Anticline. Syntectonic fluvial conglomerate (basal part of the Telemon Formation) was deposited only in the eastern part of the subsiding basin; rapidly alternating arenite-lutite sedimentation with intermittent periods of desiccation continued in the non-marine basin. Contemporaneous volcanic activity was restricted to outbursts of tuff.

Epeirogenic movements, probably in the Lower Carboniferous, preceded the deposition of fluviatile quartzose conglomerate and sand (Mount Hall Conglomerate and Raymond Sandstone). Conditions similar to those of Telemon Formation time prevailed during the deposition of the Ducabrook Formation in the later part of the Lower Carboniferous. An orogeny, probably in the early part of the Upper Carboniferous, produced broad folds in the Drummond Basin sequence.

The glacigene sediments of the Joe Joe Formation were deposited on the uneven surface of the Drummond Basin sequence in the Upper Carboniferous, and possibly in the Permian. Mild drape folds were formed in the glacigene sediments, and were slightly accentuated by small movements in the Springsure Shelf early in the Permian. The main effect of these movements was the initiation of a rapidly subsiding north-south trough (Denison Trough) with the maximum subsidence in the early stages close to its western margin. A thick sequence of freshwater sediments was deposited in the trough (Reids Dome Beds), but only a thin sequence was deposited on the western part of the shelf.

In the upper part of the Lower Permian, the Denison Trough was open to the sea for the first time. Alternating marine and fluvial-deltaic sedimentation, with several breaks in deposition, continued in the trough until the end of the Lower Permian.

The filling of the trough was marked by the deposition of sand in shallow water (Catherine Sandstone).

A sheet of fluvial quartzose sand (Colinlea Sandstone) accumulated slowly on the Springsure Shelf during upper Lower Permian times.

At the beginning of the Upper Permian, the Denison Trough no longer formed a distinct downwarp and the area became part of the western limb of a broad downwarp (Mimosa Syncline) whose axis was to the east of the Sheet area. A period of marine and brackish water sedimentation followed. It was marked by the deposition of a thin widespread sandy coquinite (Mantuan Productus Bed), outbursts of tuff, and the deposition of bentonitic clays; coal measures were deposited in the northeast. The deposition of widespread freshwater and paludal sediments with coal seams (Blackwater Group) marked the closing stages of the Upper Permian.

In the Triassic, non-marine deposition, with several local breaks, continued while the basin subsided more rapidly in the east. The red-beds of the Rewan Formation were succeeded by the fluvial Clematis Sandstone and the shallow-water labile sediments of the Moolayember Formation.

A mild orogeny, probably in the late Triassic, produced broad asymmetrical folds in the Permian-Triassic rocks in the east, and gentle warps in the west. Some of the folds and faults in the Drummond Basin were slightly rejuvenated during the orogeny.

After the orogeny, Lower Jurassic sediments were deposited over much of the area which now formed the margin of the Great Artesian Basin. The fluvial Precipice Sandstone was followed by labile clastic sedimentation in a shallow basin. The contemporaneous fluvial quartz sand (Boxvale Sandstone Member) was deposited in the west, and extended eastwards into the basin during a regression. A marine incursion possibly followed, during which chamositic mud was deposited (Westgrove Ironstone Member). The Hutton Sandstone marks a return to fluvial and lagoonal sedimentation, and the Birkhead Formation represents a gradual change to paludal deposition.

Epeirogenic uplift followed the deposition of the Great Artesian Basin sequence. The uplift was possibly related in part to Tertiary vulcanism. Flood basalts were extruded from pipes and fissures, and acid rocks, formed by differentiation of the basalt, were generated in cupolas (Minerva Hills Volcanics). Fluvial and lacustrine sediments were deposited contemporaneously with the vulcanism. In places, the basalt sheets have collapsed where the underlying soft formations have been eroded away. At least one period of lateritization preceded the extrusion of the basalts.

ECONOMIC GEOLOGY

Oil and Gas Prospects

Substantial quantities of natural gas and several small occurrences of oil have been discovered in the Springsure Sheet area, and in the areas to the south and east (see Table 1; Pls 8A, 8B). The discoveries enhance the gas, and possibly oil, potential of the Bowen Basin sequence, but the prospects of finding oil and gas in the Drummond Basin sequence in the Springsure Sheet area are not so promising. To the east and south of the Sheet area, the stratigraphic equivalents of the Drummond Basin sequence are regarded as economic basement to the Permian. The Mount Hall Conglomerate and, to a lesser degree, the Raymond Sandstone appear to be the only potential reservoir rocks. Prospective structural traps, closed in the Ducabrook Formation, may be present south and west of the Telemon and Nogoa Anticlines; lenses of Mount Hall Conglomerate form potential stratigraphic traps. The dark shale beds in the Telemon and Ducabrook Formations are potential source beds, although they may not be marine.

Several of the Permian sandstone units in the east have yielded large quantities of gas, notably the Catherine and Aldebaran Sandstones, and a sand at the top of the Peawaddy Formation (Pls 8A, 8B). The porosity of the sands is irregular, and off-structure porosity traps are possibly present. The Staircase Sandstone and the sands in the Cattle Creek and Stanleigh Formations are potential reservoir beds.

The dark shale intervals in the marine Cattle Creek, Stanleigh, Sirius, Ingelara, and Peawaddy Formations and in the Black Alley Shale are prospective source beds. Dark shale is also present in the non-marine Reids Dome Beds, Orion Formation, and Blackwater Group. In the Eddystone Sheet area, a few miles south of Ingelara homestead, the Blackwater Group contains oil shale in association with coal seams. The shale has yielded up to 30 gallons of crude oil per ton (Hill, 1957).

The most prominent exposed structural traps in the Permian sequence, Reids Dome and the Consuelo Anticline, have been unsuccessfully tested (Table 1). The Springsure Anticline is not a promising structural trap because it is breached down to the Orion Formation, and is faulted and intruded by Tertiary dykes, sills, and plugs. The Inglis Dome is closed in the Aldebaran Sandstone, and a fault in the northern plunge of the dome probably increases the closure.

Several wells have been drilled, with varying success, on closed folds in the Permian sediments under the Tertiary basalt east of the Springsure Anticline (Fig. 12). Several disconformities and low-angle unconformities in the Permian sequence in the east offer potential stratigraphic traps; the wedging out of the Catherine Sandstone at the southern end of Reids Dome is an example (see Pls 8A, 8B).

The Lower Permian Colinlea Sandstone and the Triassic Clematis Sandstone are potential reservoir sands into which hydrocarbons from the thick Permian sequence in the east could have migrated. Closed folds are not present at the surface and the gentle folds plunge to the south with a low regional dip. Reversals of the regional dip may be present to the south under the Jurassic sequence; the sands are well capped by the Peawaddy and Moolayember Formations.

No suitable structural traps appear to be present in the Jurassic sequence, which contains excellent reservoir sands. The same sands have yielded oil at Moonie.

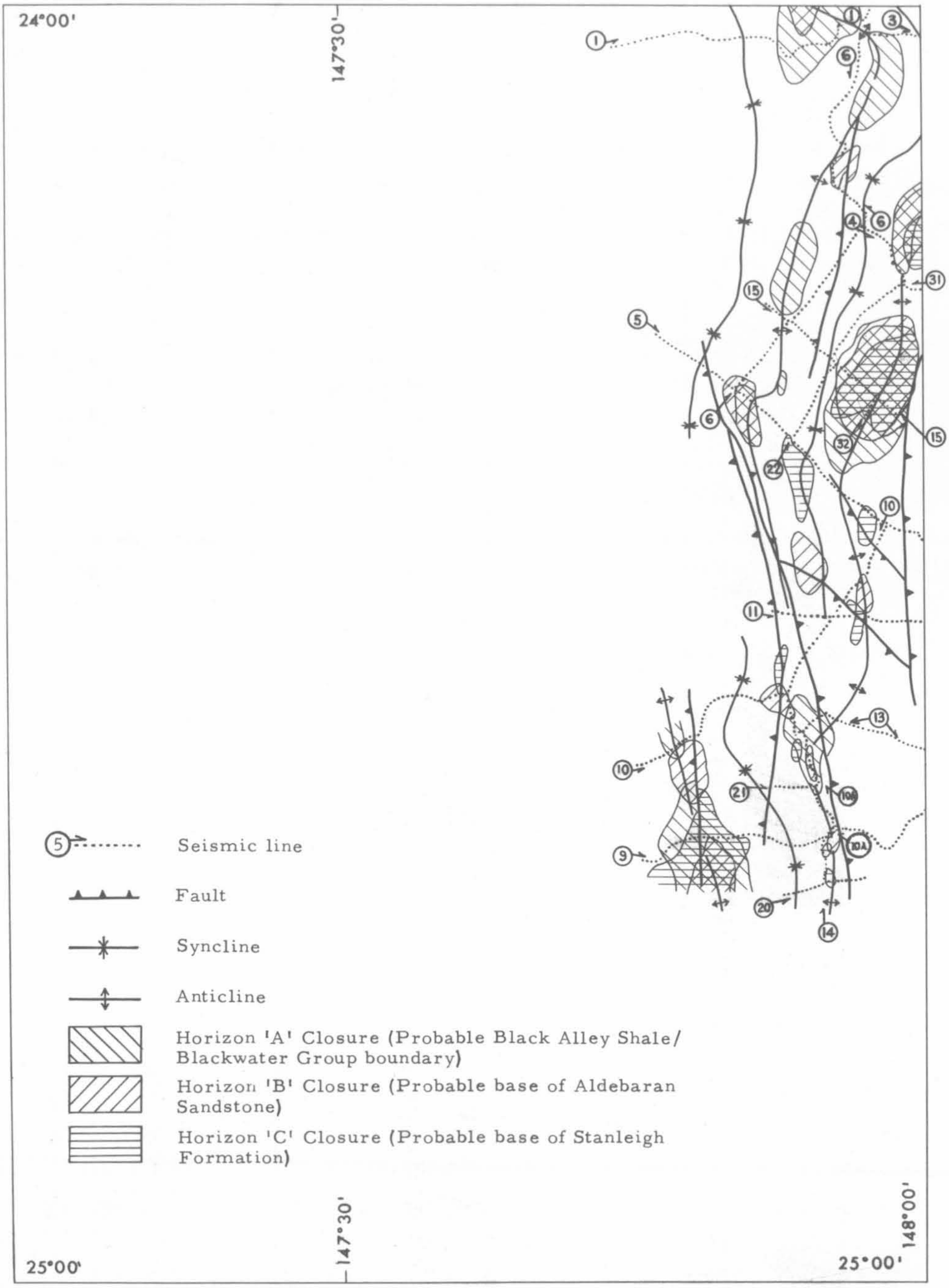
Water

Information from landholders on waterbores is presented in Mollan et al. (1964, Table 2). The waterbores shown on Plate 6 are listed in Appendix 6. In the western half of the Sheet area, the best aquifers are the Colinlea, Clematis, and Precipice Sandstones. In the east, most water is obtained from Tertiary basalt; water for Springsure is derived from the basalt. Several bores in the east have struck good supplies in Permian sandstone, particularly the Aldebaran Sandstone. Good water is obtained from bores in alluvium. Several landholders in the northwest quadrant derive good supplies from Devonian-Carboniferous rocks in the Drummond Basin. The borewater is used mainly for stock and domestic purposes.

The Nogoa River, and the Meteor, Peawaddy, Consuelo, Rocky, Carnarvon, Vandyke, and Cona Creeks are perennial, except during prolonged dry spells. Most of the creeks are fed from springs at the base of the Tertiary basalts; the water in Meteor, Peawaddy, Consuelo, Rocky, and Carnarvon Creeks is soft and clear, but the water in Vandyke and Cona Creeks is hard. The creeks to the south of the Great Dividing Range are dry for long periods. The waterholes in most of the large creeks rarely dry up.

Coal

Coal seams occur in the Reids Dome Beds (Pls 8A, 8B), the Aldebaran Sandstone (Reid, 1930), an Upper Permian coal measure unit (Pl. 8A), and the Blackwater Group; but none has been mined. Several outcrops of coal were found in the Blackwater Group during the present survey (Pl. 5, fig. 1); the seams range from a few inches to about 3 feet thick. Several waterbores, oil exploration wells (Pls 8A, 8B), and BMR No. 6 penetrated coal in the Blackwater Group. Reid (1930) reports that several coal seams were penetrated by wate bores in the Aldebaran Sandstone; outcrops of two seams, 4 inches thick, occur in th Aldebaran Sandstone in Rocky Creek. The coal seams in the Blackwater Group generally hav a gentle dip, and are the only seams of possible commercial value.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10A
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Seismic line
Fault
Syncline
Anticline
Horizon 'A' Closure (Probable Black Alley Shale/ Blackwater Group boundary)
Horizon 'B' Closure (Probable base of Aldebaran Sandstone)
Horizon 'C' Closure (Probable base of Stanleigh Formation)

Figure 12

Bentonite

Greasy soapy clay from the Black Alley Shale is pure clay of the montmorillonite type with bentonitic qualities. Numerous green, yellow, grey, and red, soft greasy clay beds are present; individual beds are generally less than 1 foot thick, and none more than 2 feet. The clays are best exposed in the southern part of Reids Dome and southwest of Wealwandangie homestead. Thompson & Duff (1965) have described the bentonitic clays.

Opal

Saint-Smith (1922) has recorded opal occurrences in amygdaloidal basalt and rhyolitic tuff, three-quarters of a mile west-southwest of Springsure, and in amygdaloidal basalt 8 miles south of Springsure. Precious opal has been reported, but is apparently rare. During the present survey, several fragments of poor-quality opal were noted in a rhyolitic tuff bed about a mile northwest of Springsure.

Alunogen

Encrustations of alunogen (aluminium sulphate), several inches thick in places, occur on vertical faces on small buttes of Colinlea Sandstone about 3 miles southeast of Vandyke homestead. The occurences have been described by Richards (1918b). Small amounts have been mined, but the deposits are not large enough to be of commercial value.

Phosphate

The sandstone in the Cattle Creek Formation contains a little apatite (Fehr, 1962), and one analysis showed 12 percent P_2O_5. Concretions with fish scales in the Ducabrook Formation, coquinitic lenses of the Mantuan *Productus* bed and the '*Eurydesma* limestone' (Cattle Creek and Stanleigh Formations), and fossiliferous concretions in the Ingelara Formation are other possible sources of phosphate.

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[illegible] XI: PERMIAN MARINE MACROFOSSILS FROM THE SPRINGSURE SHEET AREA

by

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SUMMARY

Examination and listing of fossils from 47 localities has substantially increased the number of species known from the Springsure area. The faunal subdivision into Faunas I, II, III, and IV in ascending stratigraphical order, first recognized in the marine Permian rocks of the northern part of the basin, is extended to this area.

Marine sedimentation commenced at about the same time in Springsure as in the northeastern and southeastern areas of the basin. The oldest marine fossils are in the lowest part of the Stanleigh Formation, where Fauna 1 is possibly represented. The faunas in the basal marine beds near the old Dilly Siding and the Cattle Creek Formation do not appear to be older and therefore the underlying freshwater deposits with *Glossopteris* are older than the marine beds, like the bulk of the Lower Bowen Volcanics to the east.

The faunas of the rest of the Stanleigh Formation, of all or the upper part of the marine beds at Dilly, and of the Sirius and Cattle Creek Formations, appear to represent Fauna II. The Ingelara Formation and Catherine Sandstone (as used in this Report) apparently contain Fauna III, and the overlying Peawaddy Formation with the Mantuan *Productus* Bed at the top contains Fauna IV. On this basis the marine formations below the Aldebaran Sandstone can be regarded as representing Unit A of the Middle Bowen Beds (now Tiverton Subgroup of Back Creek Group). The lowermost beds, however, were possibly laid down at the same time as the top part of the Lower Bowen Volcanics to the east. The stratigraphical interval from the Aldebaran Sandstone to the Catherine Sandstone is equivalent to Unit B of the Middle Bowen Beds (now Gebbie Subgroup), and the Peawaddy Formation and possibly the Black Alley Shale (from which no marine macrofossils are known at the surface) are equivalent to Unit C of the Middle Bowen Beds (now Blenheim Subgroup).

The faunas of the Ingelara Formation and Catherine Sandstone have similarities with Faunas IIIB and IIIC (Fauna III has been subdivided into IIIA, IIIB, and IIIC in the northern part of the basin), but differences, which seem to be largely ecological, obscure the relationship. Faunas of this age seem to be absent in the Monto and Mundubbera area, where an hiatus occurs in the sequence. The Mantuan *Productus* Bed seems to be equivalent to part of the interval from the Big *Strophalosia* Zone to the *Streptorhynchus pelicanensis* Bed of the northern part of the basin, and from the upper part of the Barfield Formation to the lower part of the Flat Top Formation in the southeast.

The marine sedimentation extends from the Lower Permian (upper Sakmarian or lower Artinskian) probably to lower Upper Permian (Kazanian).

INTRODUCTION

The rich invertebrate faunas found in some parts of the Permian sequence have aroused considerable interest. In recent years Fletcher (1945a,b), Dickins (1961), and Runnegar (1965) have described pelecypods; Campbell (1953, 1959, 1960, 1961, 1965) has described the fauna from the Ingelara Formation and spiriferoids and terebratuloids; Maxwell (1954) has described *Strophalosia*. Dorothy Hill (1957; & in unpubl. reports of

Shell and other companies) has identified marine invertebrate faunas; and J.F. Dear, in unpublished reports, has identified fossils from oil wells. Some of the fossils are illustrated in 'Permian Index Fossils of Queensland' (Hill & Woods, 1964).

There has been a tendency to think of the Bowen Basin largely in terms of the Springsure area, but the Bowen Basin regional survey has shown that both the sediments and the fauna have certain features which are not characteristic of other parts of the basin. Although the faunas are rich, they are confined to horizons separated by barren rocks, and most of the sequence is unfossiliferous. This applies particularly to the interval above the top of the Cattle Creek Formation and its equivalents. In this interval, in other parts of the basin, marine fossils are found at numerous horizons throughout the sequence, and the Springsure faunas seem best understood in this context.

The faunal subdivision of Dickins (1964a,b; 1966) into Faunas I, II, III, and IV in this stratigraphical order, first based on analysis of faunas collected in the Mount Coolon and Clermont Sheet areas, and later applied to other parts of the basin, is also used for the Springsure area. It gives a guide to a threefold subdivision of the marine rocks corresponding to the threefold subdivision used in other parts of the basin (Tiverton, Gebbie, and Blenheim Subgroups of the Back Creek Group).

The age of the marine sedimentation is considered in detail elsewhere (Dickins, MS). It is regarded as ranging from Lower Permian (upper Sakmarian or lower Artinskian) probably into lower Upper Permian (Kazanian).

I am grateful to Dr K.S.W. Campbell, Australian National University, and to Professor Dorothy Hill and Dr W.G.H. Maxwell, University of Queensland, for discussion and information on the problems of this area. Mr A.K. Denmead, Chief Government Geologist of the Geological Survey of Queensland, and Professor Hill have made important collections available for study. Dr J.F. Dear of the Geological Survey of Queensland has helped in making collections and supplying information.

The collections were made during three field seasons. Those with the prefix 'Z' were made during 1962, those with 'Sp' in 1963, and those with 'Ed' in 1964. Five of the samples are from adjacent Sheets - Sp133 from the southern part of the Emerald Sheet and Z66, Z68, and Ed169a,b from the northern part of the Eddystone Sheet. The 'KOE' numbers refer to collections made by Kimberley Oil Exploration Syndicate. Some of these numbers have appeared in published reports.

The identifications are standardized with those used in other reports on the Bowen Basin. In the main, the names correspond to those used in the 'Permian Index Fossils of Queensland' (Hill & Woods, 1964). The identifications of the terebratuloids have been taken from Campbell (1965).

IDENTIFICATIONS

Stanleigh Formation

Stanleigh Area

Z15 (probably same horizon as KOE5). In Orion Creek 3.4 miles at 123° from Spring Hill homestead.

Pelecypods

Schizodus sp. (different from S. sp. nov. A from M412a of Mackay Sheet area)

TABLE A : SPECIES DISTRIBUTION CHART, SPRINGSURE SHEET AREA

	Stanleigh Formation		Marine Beds Dilly Siding Area	Cattle Creek Formation 'Eurydesma Limestone'	Cattle Creek Formation (above 'Eurydesma Limestone')	Sirius Formation	Ingelara Formation	Catherine Sandstone	Peawaddy Formation (including Mantuan Productus Bed)
	Fauna I(?)	Fauna II					Fauna III		Fauna IV
Megadesmus nobilissimus	X								
'Megadesmus' cf. antiquatus	X								
Stutchburia cf. randsi	X								
Cypricardinia? cf. gregaria	X								
Chaenomya sp.	X	X					X		X
Oriocrassatella queenslandica	X		X						
Pseudomyalina sp.	X		X						
Megadesmus cf. gryphoides	X		X						
Eurydesma hobartense	X		X	X					
Notospirifer extensus	cf		X	X	cf	cf			
Aviculopecten sp.	X		X	X					X
Modiolus sp.	X		X		X				
Warthia sp.	X		X				X		X
Schizodus sp.		X							
Atomodesma sp.		X							
Glossopteris leaf		X							
Ingelarella profunda		X	X		cf				
Glyptoleda buarabae		cf					X		
Glyptoleda reidi		cf					X		
Gilledia oakiensis			X						
Schizodus sp. nov. A			X						
Bembexia sp. nov. A			X						
Merismopteria sp.			X						
Ptycomphalina sp.			X						
Terrakea pollex			X						
Terrakea or Cancrinella sp.			X						

	Stanleigh Formation		Marine Beds Dilly Siding Area	Cattle Creek Formation 'Eurydesma Limestone'	Cattle Creek Formation (above 'Eurydesma Limestone')	Sirius Formation	Ingelara Formation	Catherine Sandstone	Peawaddy Formation (including Mantuan Productus Bed)
	Fauna I(?)	Fauna II					Fauna III		Fauna IV
Deltopecten limacformis			X	X	X				
Strophalosia preovalis			X	X	X	X			
Ingelarella plana			X	X	X	X			
Ingelarella ovata			X			cf			
Terrakea sp.			X			X	X	X	
Strophalosia preovalis var. warwicki				X					
Strophalosia cf. preovalis or jukesi				X					
Taeniothaerus subquadratus var. acanthophorus				X					
Streptorhynchus sp. nov.				X					
Taeniothaerus subquadratus				X	cf				
Anidanthus springsurensis				X	X	X			
Neospirifer (Grantonia) cf. hobartensis				X	X	X			
Neospirifer sp. A				X	X	X	X	X	X
Plekonella sp.				X	X				X
Strophalosia jukesi					X				
Notospirifer hillae					X				
Cancellospirifer? sp.					X				
Trigonotreta or Pseudosyrinx sp.					X				
Pseudosyrinx sp. nov.					X				
Ingelarella plica					X	X			
Cancrinella farleyensis					X	X			
Lissochonetes sp.					X		X		
Cancrinella sp.						X			
Trigonotreta sp.						X			
Parallelodon sp. nov.							X		
Pachymyonia cf. P. sp. nov.							X		

	Stanleigh Formation	Marine Beds Dilly Siding Area	Cattle Creek Formation 'Eurydesma Limestone'	Cattle Creek Formation (above 'Eurydesma Limestone')	Sirius Formation	Ingelara Formation	Catherine Sandstone	Peawaddy Formation (including Mantuan Productus Bed)
	Fauna I(?)	Fauna II				Fauna III		Fauna IV
Pyramus? sp.						X		
Streblopteria? sp.						X		
Plagiostoma? sp.						X		
Elimata sp. nov.						X		
Conocardium sp.						X		
Mourlonia (Platyteichum) costatum'						X		
Cancrinella magniplica						X		
Strophalosia sp.						X		
Strophalosia cf. typica						X		
Ingelarella angulata						X		
Ingelarella ingelarensis						X		
Pseudosyrinx? sp.						X		
Maorielasma callosum						X		
Notospirifer sp. C						X	X	
Plekonella acuta						X	cf	cf
Volsellina? mytiliformis						cf	cf	X
Streblopteria sp.						X	X	X
Ingelarella mantuanensis						X	X	X
Peruvispira sp.						X		X
Anthraconeilo sp.						X		X
Glyptoleda glomerata						X		X
Stutchburia costata						X		X
Atomodesma exaratum							X	
Walnichollsia? sp.							X	
Spiriferellina? sp.							X	

	Stanleigh Formation		Marine Beds Dilly Siding Area	Cattle Creek Formation 'Eurydesma Limestone'	Cattle Creek Formation (above 'Eurydesma Limestone')	Sirius Formation	Ingelara Formation	Catherine Sandstone	Peawaddy Formation (including Mantuan Productus Bed)
	Fauna I(?)	Fauna II					Fauna III		Fauna IV
Marinurnula mantuanensis								X	X
Quadratonucula sp. nov.									X
Parallelodon sp. nov. B									X
Myonia carinata									X
Phestia sp.									X
Aviculopecten tenuicollis									X
Nuculopsis (Nuculopsis) sp.									X
Chaenomya ? cf. carinata									X
Pyramus sp.									X
Palaeosolen ? sp.									X
Astartila ? sp.									X
Mourlonia (Mourlonopsis) cf. strezleckiana									X
Mourlonia (Walnichollsia) subcancellata									X
Terrakea solida									X
Strophalosia clarkei									X
Strophalosia clarkei var. minima									X
Strophalosia ovalis									X
Neospirifer sp. B									X
Ingelarella sp.									X
Notospirifer minutus									X
Licharewia sp. nov.									X
Lissochonetes cf. semicircularis									X
Cancellospirifer ? sp.									X
Spiriferella sp.									X
Cleiothyridina sp.									X
Maorielasma globosum									X
Cladochonus sp.									X

Compiled by H.M. Doyle.

Z16 (slightly higher stratigraphically than KOE5). In Orion Creek, 3.4 miles at 126° from Spring Hill homestead.

Pelecypods
Glyptoleda cf. buarabae Campbell, 1951 (regarded as new species in Dickins, 1966; probably referable, however, to G. buarabae)
Glyptoleda cf. reidi Fletcher, 1945
Chaenomya sp. (juvenile)
Notomya sp. ind.
Atomodesma sp.

Gastropods
Indeterminate pleurotomarian

Straight nautiloid

Brachiopods
Ingelarella profunda Campbell, 1961

Glossopteris leaf

Z21A. In Orion Creek about 100 yards E. of Z21 which is in Orion Creek, 3.3 miles at 132° from Spring Hill homestead.

Pelecypods
Glyptoleda cf. reidi Fletcher, 1945

Brachiopods
Strophalosia sp. ind.

Sp6 (KOE6)*. 1.8 miles at 106° from Spring Hill homestead.

Pelecypods

Megadesmus nobilissimus (de Koninck, 1877)
Megadesmus** cf. gryphoides (de Koninck, 1877)
Chaenomya sp.
Modiolus sp.
Pseudomyalina sp. (not as definitely referable to P. mingenewensis as specimens from Homevale)
Aviculopecten sp. (large with relatively simple ribbing)
Stutchburia cf. randsi (Etheridge Jnr, 1892)(same species as in Fauna II and possibly Fauna I)
Cypricardinia? cf. gregaria (Laseron, 1910)
Oriocrassatella queenslandica Dickins, 1961

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* KOE5 and KOE6 are from the Stanleigh Formation and not from the Staircase Sandstone as suggested in Dickins (1961). The Stanleigh Formation was shown on maps current at that time as Dilly Beds.

**Previously identified as Astartila?

Gastropods
- Warthia sp.

Brachiopods
- Notospirifer cf. extensus Campbell, 1961

Sp408/2. 1.2 miles at 329° from Stanleigh homestead.

Pelecypods
- Megadesmus nobilissimus (de Koninck, 1877)
- 'Megadesmus' cf. antiquatus (Sowerby, 1838)(similar to specimens in Fauna I of St Lawrence Sheet area)
- Chaenomya sp. (similar to Chaenomya sp. in Faunas 1 and 2 of northern part of Bowen Basin)
- Eurydesma hobartense (Johnston, 1887)
- Aviculopecten sp. (large with relatively simple ribbing)
- Oriocrassatella queenslandica Dickins, 1961

Old Dilly Siding Area

Z75. 6.5 miles at 17° from Springsure.

Pelecypods
- Merismopteria sp.
- Modiolus sp. (comparable with species found elsewhere in Fauna II)
- Deltopecten limaeformis (Morris, 1845)

Brachiopods
- Ingelarella profunda Campbell, 1961

Sp. 132. On Emerald Road, 6.7 miles from Springsure.

Pelecypods
- Eurydesma hobartense (Johnston, 1887)
- Aviculopecten sp. (large species with ribbing of moderate complexity)

Brachiopods
- Terrakea pollex Hill, 1950
- Terrakea sp. (similar to species in Faunas II and IIIA in northern part of basin)
- Strophalosia preovalis Maxwell, 1954
- Ingelarella ovata Campbell, 1961
- Notospirifer extensus Campbell, 1961

Sp. 133 (KOE3). Emerald Sheet area, about 4 miles at 85° from the Minerva Siding.

Pelecypods
- Megadesmus cf. gryphoides (de Koninck, 1877)
- Modiolus sp. (species found in Fauna II)
- Aviculopecten sp. (large specimens, character of ribbing not clear)
- Stutchburia sp. ind.

Gastropods
- Warthia sp.
- Ptychomphalina sp.

Brachiopods
- Terrakea or Cancrinella sp.
- Strophalosia preovalis Maxwell, 1954
- Ingelarella plana Campbell, 1960*

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* Campbell (1961, p. 188) suggested that I. ingelarensis might be present at this locality. The additional material suggests, however, that the specimens are more satisfactorily referred to I. plana. The Strophalosia appears referable to S. preovalis sensu lato.

Notospirifer extensus Campbell, 1961
Gilledia oakiensis Campbell, 1965

Sp451. On Emerald road, 6.9 miles from springsure.

Pelecypods
Eurydesma hobartense (Johnston, 1887)(one specimen is partly decorticated, and appears to approach *E. cordatum* in shape)

Brachiopods
Terrakea sp. (as at Sp132)
Strophalosia sp?
Ingelarella plana Campbell, 1960
Notospirifer extensus Campbell, 1961 (lacks plates in brachial valve)

Ed141. 2 miles E.N.E. of Mostyndale homestead (close to horizon of Sp133).

Pelecypods
Modiolus sp?
Pseudomyalina sp.
Aviculopecten sp. (large with relatively simple ribbing)
Elimata? sp.
Stutchburia sp. ind.
Cypricardina? sp?
Schizodus sp. nov. A (appears to represent same species as in Fauna II in Mackay area, M412a - see Dickins in Hill & Woods, 1964, pl. P. 12, fig. 5)
Oriocrassatella queenslandica Dickins, 1961

Gastropods
Ptychomphalina sp.
Bembexia sp. nov. A (as in Fauna II)
Platyteichum? sp?
Warthia sp.

Brachiopods
Terrakea cf. *pollex* Hill, 1950

Sirius Formation

Z5 (KOE7). In Staircase Creek immediately S. of the Springsure-Rolleston road (immediately S. of old road crossing of creek).

Brachiopods
Terrakea sp.
Strophalosia preovalis Maxwell, 1954
Neospirifer (Grantonia) cf. *hobartensis* (Brown, 1953)
Neospirifer sp. A
Trigonotreta sp. A
Ingelarella plana Campbell, 1960
Ingelarella cf. *plica* Campbell, 1960
Ingelarella cf. *ovata* Campbell, 1961

Z5a. 300 yards S. along strike from Z5, small hill to E. of Staircase Creek.

Brachiopods
Neospirifer sp? (very large internal impressions)
Ingelarella plana Campbell, 1960
Ingelarella plica Campbell, 1960
Notospirifer cf. *extensus* Campbell, 1961

Z5b. In Staircase Creek about 1/4 mile along strike S. of Z5.

Brachiopods

Cancrinella sp.
Cancrinella farleyensis (Etheridge & Dun, 1909)
Anidanthus springsurensis (Booker, 1932)
Strophalosia preovalis Maxwell, 1954
Neospirifer sp. A
Ingelarella cf. *plana* Campbell, 1960 (similar to *I. plana* but adminicula in brachial valve longer than normal)
Pseudosyrinx sp. ind.

Cattle Creek Formation

'Eurydesma Limestone'

Sp720. 0.3 miles at 320° from AOE No. 2 Well.

Pelecypods

Eurydesma hobartense (Johnston, 1887)
Deltopecten limaeformis (Morris, 1845) (in one large specimen the ribbing simulates that of *D. illawarensis* in broadness. In the younger part, however, the ribs are too numerous for *D. illawarensis* and are like those of *D. limaeformis*)
Aviculopecten sp. ind.

Brachiopods

Anidanthus springsurensis (Booker, 1932)
Strophalosia preovalis var. *warwicki* Maxwell, 1954 (probably also *S. preovalis* var. *pristina* and *S. jukesi* of Maxwell, 1954)
Taeniothaerus subquadratus var. *acanthophorus* Fletcher, 1945
T. subquadratus (Morris, 1845) s.s.
Neospirifer (*Grantonia*) cf. *hobartensis* (Brown, 1953)
Neospirifer sp. A.
Ingelarella plana Campbell, 1960
Plekonella sp.
Streptorhynchus sp.

Bryozoans

Fenestellid, branching and forms encrusting shells

Sp732. 0.3 miles at 55° from AOE No. 2 Well.

Pelecypods

Eurydesma hobartense (Johnston, 1887)
Deltopecten limaeformis (Morris, 1845)
Aviculopecten sp.

Brachiopods

Anidanthus springsurensis (Booker, 1932)
Strophalosia cf. *preovalis* or *jukesi* of Maxwell, 1954 (probably also contains *S. preovalis* var. *warwicki* Maxwell, 1954)
Taeniothaerus subquadratus (Morris, 1845)
Taeniothaerus subquadratus var. *acanthophorus* Fletcher, 1945
Neospirifer (*Grantonia*) cf. *hobartensis* (Brown, 1953)
Neospirifer sp. A
Ingelarella plana Campbell, 1960
Notospirifer extensus Campbell, 1961 (brachial valves not very satisfactory but pedicle valves identical with *N. extensus*)

Plekonella sp.
Streptorhynchus sp. nov. (differs from S. pelicanensis in coarser ribbing)

Bryozoans
Fenestellid, branching and encrusting shells

Sp733. In Little Gorge Creek 1.8 miles S. of AOE No. 1 Well.

Brachiopods
Strophalosia sp. ind.
Neospirifer sp. A
Notospirifer sp. ind.
Other fragments

Single corals

Above 'Eurydesma Limestone'

Z46. In Cattle Creek, 2.6 miles at 170° from AOE No. 2 Well.

Pelecypods
Myonia sp. ind.
Cypricardinia? sp. ind.

Gastropods

Warthia sp. (or cephalopod)
Bembexia sp. ind.

Brachiopods
Cancrinella farleyensis (Etheridge & Dun, 1909)
Strophalosia preovalis Maxwell, 1954.
Lissochonetes sp.
Neospirifer (Grantonia) cf. hobartensis (Brown, 1953)
Neospirifer sp. A
Ingelarella cf. plana Campbell, 1960
Notospirifer cf. hillae Campbell, 1961
Cancellospirifer? sp.
Pseudosyrinx sp. nov.

Bryozoans
Branching and fenestellid forms

Crinoid stems

Single corals

Float close to Z46

Brachiopods
Taeniothaerus cf. subquadratus (Morris, 1845)
Neospirifer sp. A
Ingelarella cf. plana Campbell, 1960

Sp209C. In Cattle Creek, 2.4 miles at 183° from AOE No. 2 Well.

Brachiopods
Neospirifer sp. A

Conulariid

Sp460. 1.2 miles at 320° from AOE No. 2. Well.

Pelecypods
  Modiolus sp. (as in Fauna II elsewhere)

Brachiopods
  Cancrinella farleyensis (Etheridge & Dun, 1909)
  Anidanthus springsurensis (Booker, 1932)
  Strophalosia cf. *preovalis* Maxwell, 1954
  Neospirifer sp. A
  Ingelarella cf. *profunda* Campbell, 1961
  Ingelarella plana Campbell, 1960
  Ingelarella plica Campbell, 1960
  Notospirifer cf. *extensus* Campbell, 1961 (or possibly a young *N. hillae*)
  Rhychonellid gen. et sp. (lacks lateral plication)

Sp747. 6 miles 186° from AOE No. 2 Well.

Brachiopods
  Neospirifer (*Grantonia*) cf. *hobartensis* (Brown, 1953)?
  Ingelarella cf. *plana* Campbell, 1960

Sp748. 5.4 miles at 183° from AOE No. 2 Well

Pelecypods
  Deltopecten limaeformis (Morris, 1845)

Gastropods
  Indeterminate spired form

Brachiopods
  Strophalosia jukesi of Maxwell, 1954 (probably *S. preovalis* also present)
  Neospirifer sp. A
  Trigonotreta or *Pseudosyrinx* sp.
  Ingelarella cf. *plana* Campbell, 1960
  Notospirifer hillae Campbell, 1961
  Plekonella sp.

Bryozoans
  Fenestellids and stenoporoids

Relationships

The collections identified from the Stanleigh (including the Dilly Beds), Sirius, and Cattle Creek Formations show a uniformity throughout.* Faunally, the evidence for the oldest age is shown by the samples Sp6 and Sp408/2 from the basal Stanleigh, which contain '*Megadesmus*' cf. *antiquatus* and *Aviculopecten* with relatively simple ribbing. These indicate that possibly Fauna 1 is represented. Whether Fauna I or only Fauna II is represented near Dilly is not clear, but *Keeneia* sp. (identified in the collections of the Queensland Geological Survey) suggests that in part it is not younger than basal Fauna II. The rest of the faunas seem to belong to Fauna II.

The faunas from the Dilly area, the part of Stanleigh Formation above the base, and the '*Eurydesma* Limestone' of Reids Dome, all seem close to each other and to the faunas found near Homevale, Mackay Sheet area, and at stratigraphically equivalent positions in the northern part of the basin. It is also close to the fauna of the Buffel Formation of the Mundubbera and Monto Sheet areas (including the Cracow area). These beds contain, in particular, *Eurydesma hobartense*, *Deltopecten limaeformis*, *Cancrinella farleyensis*,

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* This applies also to the subsurface fauna identified from the Cattle Creek Formation from Reids Dome No. 1 by J.F. Dear in Appendix 2.

Terrakea pollex, varieties of Strophalosia preovalis, Anidanthus springsurensis, Taeniothaerus spp., Neospirifer (Grantonia) cf. hobartensis, and Ingelarella profunda. Differences such as the rarity of Notospirifer hillae in the Springsure area and the common occurrence of N. extensus seem to be largely ecological. When all the species represented are taken into account there seems little basis for regarding these horizons as younger than Fauna II or even younger than the fauna at Homevale. It follows, therefore, for example, that the range of Glyptoleda must be extended down into Fauna II.

In the Springsure area, Ingelarella plana has been recorded previously only from the Sirius Formation and the upper part of the Cattle Creek Formation so that its occurrence at Dilly, and in the 'Eurydesma Limestone' of Reids Dome, extends its range. As a result of re-examination of material from the St Lawrence Sheet area it appears that I plana occurs at SL60, 2½ miles north of Marylands homestead, with a fauna very similar to that from the beds at Homevale.

The fauna from the Sirius Formation and from the part of the Cattle Creek Formation above the 'Eurydesma Limestone' contains Ingelarella plica and in this seems to differ from that found lower.

On the basis of the occurrence of typical Fauna II species in the Sirius Formation such as Cancrinella farleyensis, Anidanthus springsurensis, Strophalosia preovalis, and Neospirifer (Grantonia) cf. hobartensis, and their absence in Fauna IIIA immediately below the 'Wall Sandstone' in the northern part of the basin, and the intermingling of forms referable to I. plica, I. ingelarensis, I. ovata, I. profunda, and I. plana in Fauna IIIA, it appears that the Sirius Formation is slightly older than the base of the 'Wall Sandstone', i.e. of the Gebbie Subgroup.

The correlations of the Permian sequence in the Springsure area with that in other parts of the basin and the relationship with the underlying and overlying formations are shown in Figure A.

From these data and from the occurrence of Glossopteris in both, it seems that the freshwater beds underlying the marine beds of the Springsure area can, in a general way, be correlated with the main part of the Lower Bowen Volcanics to the east.

Ingelara Formation

Z66. Eddystone Sheet area, in Dry Creek 5 miles at 263° from Ingelara homestead.

Pelecypods

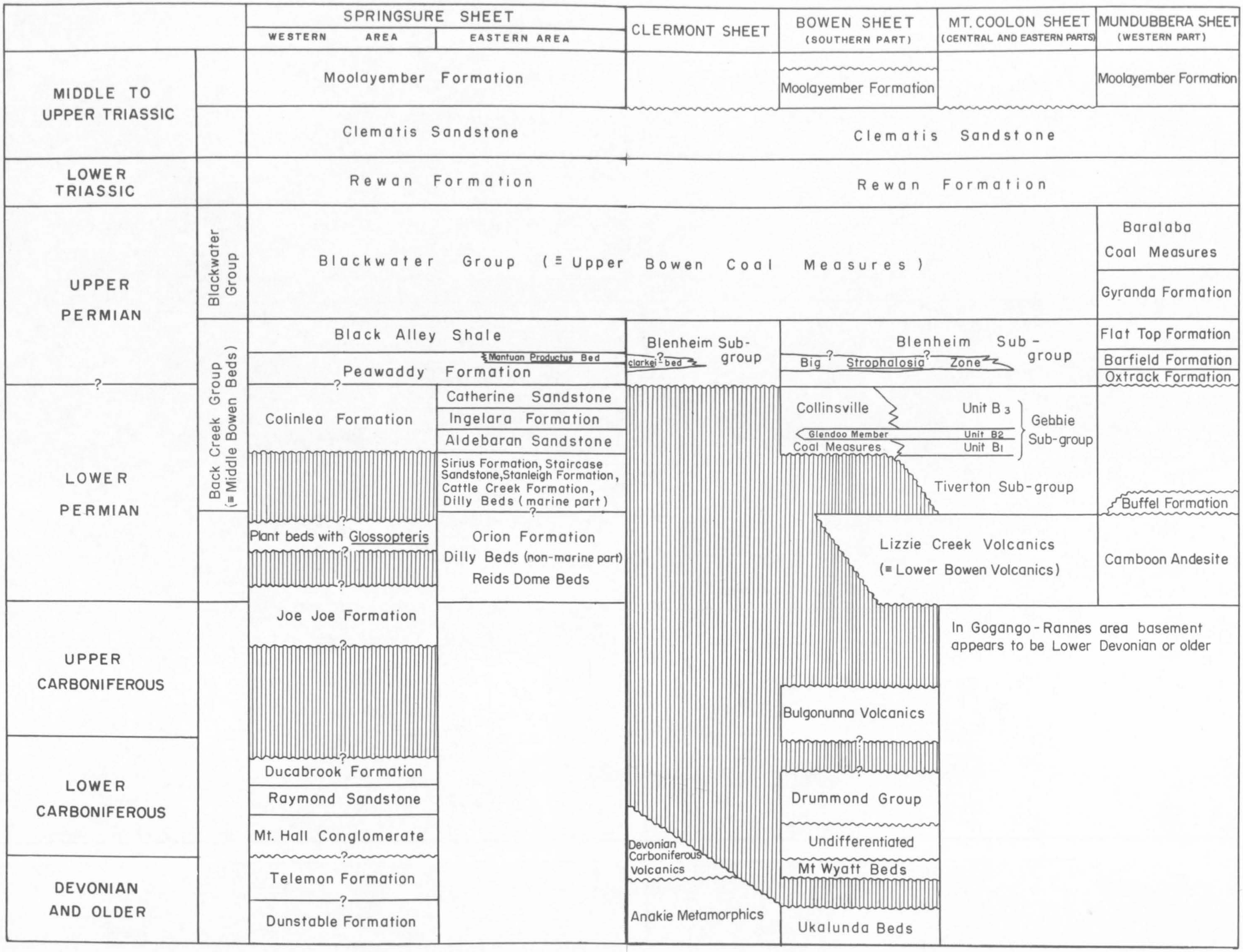
- Anthraconeilo sp.
- Glyptoleda reidi Fletcher, 1945
- Glyptoleda glomerata Fletcher, 1945
- Glyptoleda buarabae Campbell, 1951
- Chaenomya sp. (most like species in Fauna IIIA, but distinct from those in Peawaddy and Barfield Formations - elongated and distinctly produced in front of umbo, sulcate)
- Volsellina? cf. mytiliformis (Etheridge Jnr., 1892)

Gastropods

- Warthia sp.
- Platyteichum costatum Campbell, 1953

Brachiopods

- Cancrinella magniplica Campbell, 1953
- Strophalosia sp. (flatter than S. ovalis or S. brittoni var. gattoni. Possibly a small S. clarkei but may represent a new species)
- Strophalosia cf. typica (Booker, 1929)(no sulcus, poorly developed adductor muscle platform)


SPRINGSURE SHEET
WESTERN AREA
EASTERN AREA
CLERMONT SHEET
BOWEN SHEET (SOUTHERN PART)
MT. COOLON SHEET (CENTRAL AND EASTERN PARTS)
MUNDUBBERA SHEET (WESTERN PART)
MIDDLE TO UPPER TRIASSIC
Moolayember Formation
Moolayember Formation
Moolayember Formation
Clematis Sandstone
Clematis Sandstone
LOWER TRIASSIC
Rewan Formation
Rewan Formation
UPPER PERMIAN
Blackwater Group
Blackwater Group (≡ Upper Bowen Coal Measures)
Baralaba Coal Measures
Gyranda Formation
Back Creek Group (≡ Middle Bowen Beds)
Black Alley Shale
Mantuan Productus Bed
Peawaddy Formation
Blenheim Sub-group
clarkei bed
Blenheim Sub-group
Big Strophalosia Zone
Flat Top Formation
Barfield Formation
Oxtrack Formation
?
LOWER PERMIAN
Colinlea Formation
Catherine Sandstone
Ingelara Formation
Aldebaran Sandstone
Sirius Formation, Staircase Sandstone, Stanleigh Formation, Cattle Creek Formation, Dilly Beds (marine part)
Collinsville
Glendoo Member
Coal Measures
Unit B3
Unit B2
Unit B1
Gebbie Sub-group
Tiverton Sub-group
Buffel Formation
Plant beds with Glossopteris
Orion Formation
Dilly Beds (non-marine part)
Reids Dome Beds
Lizzie Creek Volcanics (≡ Lower Bowen Volcanics)
Camboon Andesite
UPPER CARBONIFEROUS
Joe Joe Formation
In Gogango - Rannes area basement appears to be Lower Devonian or older
Bulgonunna Volcanics
LOWER CARBONIFEROUS
Ducabrook Formation
Raymond Sandstone
Mt. Hall Conglomerate
Drummond Group
Undifferentiated
Devonian Carboniferous Volcanics
Mt Wyatt Beds
DEVONIAN AND OLDER
Telemon Formation
Dunstable Formation
Anakie Metamorphics
Ukalunda Beds

Ingelarella angulata Campbell, 1959
Ingelarella ingelarensis Campbell, 1960
Pseudosyrinx? sp.
Streptorhynchus sp. ind.

This sample is from the main nodular fossiliferous horizon which is apparently the lower sandy part of the Ingelara referred to by Campbell (1953, p. 3).

J.F. Dear has kindly lent me three specimens of Strophalosia from his locality D91, in Dry Creek, 'from a boulder approximately 20 yards below the main outcrop of the lower (nodular) horizon of the Ingelara Shale'. Two of the specimens (F6133) are brachial valves and the third (F6132) is an incomplete pedicle valve which has a well developed adductor muscle platform and is possibly referable to S. ovalis or S. brittoni var. gattoni.

Sp115. In Sandy Creek, 7.2 miles at 277° from Springwood homestead.

Pelecypods
- Parallelodon sp. nov. (posterior carina tends to be rounded and radiating ribs are of a similar order over whole of the shell)
- Pachymyonia cf. P. sp. nov. from Fauna IIIA
- Pyramus sp?
- Modiolus? sp. ind.
- Streblopteria? sp.
- Plagiostoma? sp.
- Elimata sp. nov.
- Stutchburia costata (Morris, 1845)
- Conocardium sp.

Gastropods
- Peruvispira sp. (angular whorl cross-section, lowest lira set back from periphery)

Brachiopods
- Cancrinella cf. magniplica Campbell, 1953
- Terrakea sp. (rather broad and umbo blunt - considerable umbonal thickening in some specimens)
- Lissochonetes sp.
- Neospirifer sp. A
- Ingelarella mantuanensis Campbell, 1960
- Notospirifer sp. C (plicae more distinct than in N. extensus, pedicle valve not swept back from umbo as in N. minutus, closely related to N. cf. extensus in Glendoo Member and from Fauna IIIC in Homevale area)
- Plekonella acuta Campbell, 1953
- Other rhynchonellids
- Maorielasma callosum Campbell, 1965

Large single corals

SP750/2. 2.7 miles at 322° from Ingelara homestead.

Pelecypods
- Glyptoleda glomerata Fletcher, 1945
- Streblopteria sp.

Gastropods
- Platyteichum costatum Campbell, 1953

Brachiopods
- Ingelarella sp. ind.

Wood fragments

Ed78. West Branch of Dry Creek, about 3 miles W of N of Early Storms homestead.

Pelecypods
- *Glyptoleda* sp.

Gastropods
- *Platyteichum costatum* Campbell, 1953

Brachiopods
- *Strophalosia* cf. *typica* (Booker, 1929)
- *Ingelarella ingelarensis* Campbell, 1960
- *Streptorhynchus* sp. ind.

Catherine Sandstone

Sp383/3. 4.4 miles at 344° from Croydon Hills homestead.

Pelecypods
- *Parallelodon* sp. ind.
- *Volsellina*? cf. *mytiliformis* (Etheridge Jnr, 1892)
- *Atomodesma exaratum* Beyrich, 1864 (one specimen may have two anterior grooves or this may be caused by crushing)
- *Plagiostoma*? sp.
- *Conocardium* sp.

Gastropods
- *Walnichollsia*? sp. (carinate at all growth stages)

Brachiopods
- *Neospirifer* sp. A
- *Ingelarella mantuanensis* Campbell, 1960
- *Notospirifer* sp. C
- *Spiriferellina*? sp.
- *Marinurnula mantuanensis* Campbell, 1965

Crinoid ossicles

Sp384/1. 1.1 miles at 256° from Croydon Hills homestead.

Brachiopods
- *Terrakea* sp. (as in Ingelara Formation and other Catherine Sandstone localities)
- *Neospirifer* sp. ind.
- *Plekonella* cf. *acuta* Campbell, 1953

Sp385/1. 1.2 miles at 299° from Croydon Hills homestead.

Brachiopods
- *Terrakea* sp. (as at other Catherine Sandstone localities)

SP385/4. 0.9 miles at 290° from Croydon Hills homestead.

Pelecypods
- *Streblopteria* sp.

Brachiopods
- *Terrakea* sp. (as in other Catherine Sandstone localities, rather geniculate, with occasional umbonal thickening sulcate).
- *Notospirifer* sp. C

Sp750/3. 2.8 miles at 335° from Ingelara homestead.

Terebratuloid brachiopods

Relationships

The fauna from the Catherine Sandstone is from its lower part and, because of their similarity, the faunas of the Ingelara Formation and Catherine Sandstone are considered together. Sp750/2 is found in the Ingelara Formation immediately below Sp750/3 in the Catherine Sandstone, and forms a lithological and faunal link with Z66 in indicating that it too is to be referred to the Ingelara Formation. Stratigraphically higher faunas in Dry Creek previously regarded as belonging to the Ingelara Formation (upper mudstone of Campbell, 1953, p. 3.), and represented in this Report by Ed164a,b, are now referred to the Peawaddy Formation. South of Sp750/3 and Sp750/2 the Catherine Sandstone wedges out and the Peawaddy Formation rests directly on the Ingelara Formation. As shown in the next section, the fauna of the Peawaddy Formation appears to be distinctly younger than that of the Ingelara Formation or Catherine Sandstone.

Although the Ingelara Formation and Catherine Sandstone contain species which continue into Fauna IV, it seems more satisfactory to refer the faunas of these two formations to Fauna III. *Parallelodon* sp. nov. B,. *Myonia carinata*, *Platyteichum coniforme*, *Terrakea solida*, *Strophalosia ovalis*, *Neospirifer* sp. B, *Trigonotreta* sp. B, *Notospirifer minutus*, and *Licharewia* sp. nov., as well as other species characteristic of Fauna IV, are absent from these formations. On the other hand, they contain different species of *Parallelodon*, *Myonia* (or *Pachymyonia*), *Chaenomya*, *Terrakea*, *Strophalosia*, and *Notospirifer* which suggest affinity with Fauna III. The fauna appears to be closest to IIIB (Glendoo Member and equivalents) or IIIC, although it could possibly be intermediate between IIIC and IV. This evidence, therefore, suggests that the Ingelara Formation and Catherine Sandstone, as well as the Aldebaran Sandstone, are to be related to the Gebbie Subgroup, which is characterized lithologically by containing quartz sandstones.

Peawaddy Formation

With the exception of Sp169, Sp729, and Ed169a,b, which are found in a lower stratigraphical position, all the samples are from the Mantuan *Productus* Bed.

Z68. Eddystone Sheet area, in Dry Creek, 4.6 miles at 243° from Ingelara homestead.

Pelecypods
    Quadratonucula sp. nov.

Gastropods
    Warthia sp. ind.

Z72. In Sandy Creek 2.4 miles at 277° from Mt Carnarvon

Pelecypods
    Parallelodon sp. nov. B
    Myonia cf. *carinata* (Morris, 1845)
    Volsellina? *mytiliformis* (Etheridge Jnr, 1892)
    Aviculopecten sp.

Brachiopods
    Terrakea solida (Etheridge & Dun, 1909)
    Strophalosia ovalis Maxwell, 1954 (some specimens similar to *S. brittoni* var. *gattoni*)
    Neospirifer sp. B
    Ingelarella cf. *mantuanensis* Campbell 1960

Fenestellid bryozoans

Crinoid cup

Z73. Small quarry on road into Reids Dome, 2.2 miles at 312° from 'Ten Mile Hut'.

Brachiopods
Terrakea sp. ind.
Strophalosia clarkei (Etheridge Snr, 1872)
Strophalosia ovalis Maxwell, 1954

Bryozoans
Fenestellid and branching forms, and forms encrusting *Strophalosia* shells

Sp169. 3.3 miles at 58° from Tanderra (previously Nardoo) homestead.

Pelecypods
Chaenomya sp. (small but of Fauna IV type)
Indet. shell fragments

Gastropods
Warthia sp.

Sp378/1. 2.3 miles at 45° from Kareela homestead.

Pelecypods
Myonia sp. ind.

Brachiopods
Terrakea solida (Etheridge & Dun, 1909)
Strophalosia ovalis Maxwell, 1952 (some coarse spines on ears otherwise fine)
Quartz pebble ½ inch across in matrix

Sp391. Small quarry immediately N. of road, 4.6 miles at 242° from Wealwandangie homestead.

Pelecypods
Phestia sp. (species referred to Nuculana in previous reports are now assigned to *Phestia* - see Dickins, 1963)
Myonia carinata (Morris, 1845)

Gastropods
Indet. pleurotomariid

Brachiopods
Terrakea solida (Etheridge & Dun, 1909) (wide variety, identified in Queensland Index Fossils as *T*. cf. *brachythaera*)
Strophalosia clarkei Etheridge Snr, 1872 *
Strophalosia clarkei var. *minima* Maxwell, 1954 *
Strophalosia ovalis Maxwell, 1954 *
Ingelarella mantuanensis Campbell, 1960
Maorielasma globosum Campbell, 1965

Fenestellid and branching bryozoans

Crinoid ossicles

Single corals

Sp440/1. In Peawaddy Creek, 4 miles at 284° from Consuelo homestead.

Brachiopods
Terrakea solida (Etheridge & Dun, 1909)
Strophalosia sp. ind.

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* (The three species of *Strophalosia* identified seem to have a similar spine pattern - numerous fine spines over the body of the shell and coarser spines on the ears).

  Neospirifer sp. A.
  Neospirifer sp. B.
  Notospirifer minutus Campbell, 1960

Branching bryozoans

Sp435. 1.2 miles at 302° from Consuelo homestead.

Pelecypods
  Aviculopecten tenuicollis (Dana, 1847)
  Aviculopecten sp. ind.

Gastropods
  Indet. pleurotomariid

Brachiopods
  Terrakea solida (Etheridge & Dun, 1909)
  Strophalosia clarkei (Etheridge Snr, 1872) predominates in numbers amongst *Strophalosia*)*
  Strophalosia cf. *ovalis* Maxwell, 1954
  Neospirifer sp. A
  Notospirifer minutus Campbell, 1960
  Plekonella sp.
  Maorielasma globosum Campbell, 1965

Single corals

Sp647. 2.2 miles at 12° from Buckland Plains homestead

Brachiopods
  Terrakea solida (Etheridge & Dun, 1909)
  Strophalosia ovalis Maxwell, 1954

Branching bryozoans

Single corals

Sp648/1. 1.2 miles at 200° from Tanderra homestead

Brachiopods
  Ingelarella mantuanensis Campbell, 1960

Sp649. 2.0 miles at 188° from Tanderra homestead.

Some of the nodular material is very similar in appearance to that in Geological Survey of Queensland from Boat Mountain, Wealwandangie.

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* The taxonomic relationship of *Strophalosia clarkei*, *S. clarkei* var. *minima*, *S. ovalis*, and *S. brittoni* var. *gattoni* has presented considerable difficulties. During the Bowen Basin survey some thousands of specimens belonging to these species have been available for examination. Important characters intergrade, such as the depth and width of the valves and development of the umbo, dental callosities, and ventral adductor muscle platform. In mature specimens, however, the ventral adductor muscle platform is generally moderately well developed and the overall spine pattern appears to be similar. In these circumstances, it might be better to regard these groups as varieties or subspecies, rather than referring them to three separate species. In numbers, *S. clarkei* var. *minima* predominates in the southeast part of the basin, *S. clarkei* in the northern part, and *S. ovalis* in the southwest, suggesting that geographical subspecies may be represented. The distribution pattern, however, is complex-for example, at Sp435, in the southwest, *S. clarkei* predominates.

Pelecypods
Nuculopsis (Nuculopsis) sp.
Anthraconeilo sp.
Phestia sp.
Glyptoleda glomerata Fletcher, 1945
Myonia carinata (Morris, 1845)
Chaenomya? cf. carinata Etheridge Jnr, 1892
Chaenomya sp. (apparently Fauna IV type)
Pyramus? sp. (transverse oval form, generally similar to form in CL12/1 of Clearmont area)
Palaeosolen? sp.
Aviculopecten sp. ind.
Stutchburia costata (Morris, 1845)
Astartidae gen. et sp. nov. B. (as in Fauna IV) *
Conocardium sp.

Gastropods
Warthia sp.
Mourlonia (Mourlonopsis) cf. strzeleckiana (Morris, 1845) (has relatively long slit)
Mourlonia (Walnichollsia) cf. subcancellata (Morris, 1845) (as at MC423 of Mt Coolon Sheet area - early whorls carinate, later rounded)
Pleurotomariidae gen. et sp. (distinct ridge at periphery, whorl outline rectangular, distinct nodes on upper whorl surface)

Brachiopods
Terrakea solida (Etheridge & Dun, 199)
Strophalosia ovalis Maxwell, 1954
Neospirifer sp. A
Ingelarella mantuanesis Campbell, 1960 (some approach I. ingelarensis in depth of sulcus)
Notospirifer minutus Campbell, 1960
Licharewia sp. nov. (as in Fauna IV elsewhere)
Plekonella sp.
Maorielasma globosum Campbell, 1965

Single corals

The matrix contains greenish cherty fragments up to 3/4 inch across.

Sp719. 1.4 miles at 312° from Mt Serocold.

Brachiopods
Terrakea solida (Etheridge & Dun, 1909) (specimens match those from Lonesome Creek road quarry of Monto Sheet area)
Strophalosia sp. ind.
Ingelarella mantuanensis Campbell, 1960
Notospirifer minutus Campbell, 1960
Marinurnula mantuanensis Campbell, 1965

Fenestellid bryozoans

Sp729. 2.1 miles at 43° from Tanderra homestead.

Pelecypods
Glyptoleda sp. ind.
Astartila? sp. (juvenile specimen but similar to species in Fauna IV)

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* Australia (Pleurikodonta) elegans Runnegar, 1965

Gastropods
    Warthia sp.
    Mourlonia (*Mourlonopsis*) cf. *strezleckiana* (Morris, 1845)

Brachiopods
    Ingelarella sp. (one specimen of *I. pelicanensis* type as in Lonesome Creek road quarry)

Scaphopods

Sp731/2. 1.2 miles at 300° from Mt Serocold.

Pelecypods
    Myonia carinata (Morris, 1845)
    Myonia sp. ind.
    Aviculopecten sp. ind.
    Heteropecten sp. ind.

Brachiopods
    Terrakea solida (Etheridge & Dun, 1909)
    Strophalosia cf. *ovalis* Maxwell, 1954
    Neospirifer sp. A
    Ingelarella mantuanensis Campbell, 1960
    Notospirifer minutus Campbell, 1960

Ed167. West branch of Dry Creek about 3 miles W. of N. of Early Storms homestead.

Pelecypods
    Aviculopecten sp. (Fauna IV type with many intermediate ribs)

Gastropods
    Peruvispira sp.

Brachiopods
    Terrakea solida (Etheridge & Dun, 1909)

Branching and fenestellid bryozoans

Ed169a. Dry Creek, about 2 miles N. of Early Storms homestead.

Pelecypods
    Nuculopsis (*Nuculopsis*) sp.
    Streblopteria sp.

Brachiopods
    Lissochonetes cf. *semicircularis* Campbell, 1953
    '*Licharewia*' or *Pseudosyrinx* sp.
    Cancellospirifer? sp.
    Spirigerella sp.
    Cleiothyridina sp.
    Plekonella cf. *acuta* Campbell, 1953
    Indet. dielasmatid

Branching bryozoans

Corals
    Cladochonus sp.
    Single corals

Ed169b. As for Ed169b. 4 feet higher stratigraphically.

Pelecypods
  Phestia sp.
  Streblopteria sp.

Brachiopods
  Cleiothyridina? sp. ind.
  Indet. dielasmatid

Branching and fenestellid bryozoans

Corals
  Cladochonus sp.

Relationships

The fauna from the lower part of the Peawaddy Formation (Sp169, Sp729, & Ed169 a,b) is relatively poor, but *Astartila*? sp. and *Ingelarella* sp. afford slim evidence that Fauna IV is represented. In the subsurface, the Peawaddy Formation can be traced to Glentulloch No. 1 well, where *Terrakea solida* and *Strophalosia ovalis* have been recorded from core 11 (2510-2530 ft) at the base of the Peawaddy Formation (Dear, 1962). This is evidence for correlating the base of the Peawaddy Formation with the Oxtrack Formation of the Monto and Mundubbera areas and for considering that it is not older than the base of the Blenheim Subgroup in the northern part of the Bowen Basin. In correlations of this nature, evidence based on one or two species whose ranges are poorly known may be unreliable. This is especially so when identification is based on small morphological differences whose taxonomic and stratigraphical significance is obscure. In this case, however, the identifications seem clear-cut, and a great deal of information is available on the ranges of *T. solida* and *S. ovalis*. The fauna of the Oxtrack Formation and its correlation with the Springsure sequence is considered further in Dickins (MS).

The Mantuan *Productus* Bed contains many species which are characteristic of Fauna IV and which do not occur in Fauna III. In a general way, it is apparently equivalent to the upper Barfield and lower Flat Top Formation of the southeastern part of the basin. Whether it is equivalent to the Big *Strophalosia* Zone and the *clarkei*-bed of the northern part or to the *Streptorhynchus pelicanensis* Bed and the pelecypod bed or to both horizons together, is a more difficult problem because, with a few exceptions, the characteristic species of the Mantuan *Productus* Bed are found at both levels *.

The Catherine Sandstone of Campbell (1960, 1961, after Hill, 1957) contained the Catherine Sandstone as restricted in the main Report and all the Peawaddy Formation below the Mantuan *Productus* Bed. When this is taken into account, the correlations of the Springsure sequence made here correspond closely with Campbell's conclusions. If the lower part of the Big *Strophalosia* Zone were equivalent to the Ingelara Formation and the upper part of the Mantuan *Productus* Bed (Maxwell, 1954, p. 535), the Big *Strophalosia* Zone would contain an hiatus representing the Catherine Sandstone and most of the Peawaddy Formation. Field examinations do not show any hiatus, and lithological, bedding, and faunal relationships throughout show that such a break is unlikely. Faunal evidence discussed earlier indicates that the Big *Strophalosia* Zone is entirely younger than the Ingelara Formation.

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* Evidence for correlating the *clarkei*-bed of the Clermont Sheet area with the Big *Strophalosia* Zone of the Bowen area is considered in Dickins (1964b), and for correlating the Crocker Formation of the Duaringa area with the pelecypod bed of the Clermont area and the *Streptorhynchus pelicanensis* of the Bowen area in Dickins (1969).

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APPENDIX 2 : PALAEONTOLOGICAL REPORT ON CORE 2 (1008-25FT) AUSTRALIAN OIL EXPLORATION NO. 1 (REIDS DOME)

by J.F. Dear

Locality: Australian Oil Exploration No. 1 (Reids Dome), 29 miles southwest of Rolleston; latitude 24°47'25"S., longitude 148°18'19"E.

Determinations

Strophalosia preovalis Maxwell
Taeniothaerus subquadratus var. acanthophorus Fletcher
Anidanthus springsurensis (Booker)
Terrakea sp. ind.
Linoproductus sp.
Streptorhynchus sp.
Ingelarella cf. plica Campbell
Grantonia sp.
Trigonotreta sp.
Cancellospirifer sp.
Neospirifer sp.
Cleiothyridina sp.
Pseudosyrinx sp.
Volsellina sp.
Aviculopecten sp.
Stutchburia cf. costata (Morris)
?Astartila sp.
Peruvispira sp.
Stenopora sp.
Fenestella fossula Lonsdale
Polypora pertinax Laseron
Polypora montuosa (Laseron)

Age: Lower Permian

Remarks

The core when broken and leached in acid yielded several species that had not been recorded by Hill (1955) in a previous examination of the material. These additional forms include Anidanthus springsurensis, Linoproductus sp., Streptorhynchus sp., Ingelarella cf. plica, Cleiothyridina sp., Pseudosyrinx sp., Stutchburia cf. costata, and Peruvispira sp; they have, however, provided only limited evidence on the relationships of the assemblage to the faunas from Dilly, and those from the 'Eurydesma Limestone' and the upper part of the Cattle Creek Formation at Reids Dome.

Specimens of Strophalosia preovalis are abundant in the 'Eurydesma Limestone' and the upper Cattle Creek Formation; but in the Dilly Beds S. preovalis var. pristina Maxwell and S. jukesi var. concava Maxwell are the most common species. Taeniothaerus subquadratus var. acanthophorus occurs profusely in the 'Eurydesma Limestone'; it is found also at Dilly, and has been identified in recent Geological Survey of Queensland collections from the upper part of the Cattle Creek Formation in Cattle Creek. Most collections from the upper part of the Cattle Creek Formation contain Anidanthus springsurensis, and the species occurs also in the 'Eurydesma Limestone' and in the

Dilly Beds. The fragmentary specimens of *Terrakea* are of little value in correlation. *Linoproductus* has successive trails preserved on the brachial valve and resembles the species from the upper part of the Cattle Creek Formation. *Linoproductus* has not been observed in assemblages from Dilly or from the '*Eurydesma* Limestone'.

Streptorhynchus sp. is too poorly preserved to permit accurate comparison with the small species of *Streptorhynchus* from the '*Eurydesma* Limestone'.

The Ingelarellid species most closely resembles *Ingelarella plica* from the upper part of the Cattle Creek Formation, but differs in possessing a deeper median sinus on the pedicle valve and six costae on each of the lateral slopes. No comparable form has been recognized in either the Dilly Beds or in the '*Eurydesma* Limestone'. A small lamellose spiriferid with six or seven plications on each lateral slope has been assigned to *Trigonotreta*; the plications nearest the median sinus bifurcate. This species has not been observed previously in collections from the Springsure district. *Grantonia* sp. and *Cancellospirifer* sp. are very similar to species from the upper part of the Cattle Creek Formation; representatives of these two genera are uncommon in the Dilly Beds and '*Eurydesma* Limestone'. *Neospirifer* sp. is the large weakly fasciculate species that occurs at Dilly and in the two major fossiliferous horizons of the outcropping Cattle Creek Formation at Reids Dome. *Cleiothyridina* ranges through most of the marine Permian succession of the Springsure Shelf.

Dense, fine punctae distinguish the large spiriferid assigned to the genus *Pseudosyrinx* Weller; the external ornament is not preserved.

Stutchburia cf. *costata* resembles the species found in the upper part of the Cattle Creek Formation, but differs in its much smaller size.

The bryozoan species are long ranging and are known to occur in the '*Eurydesma* Limestone' at Reids Dome.

In conclusion, it is known from the stratigraphic position of the core that the assemblage underlies the '*Eurydesma* Limestone'. The affinities of the fauna, on the limited evidence available, are closer to the assemblages from the '*Eurydesma* Limestone' and the upper part of Cattle Creek Formation than to those from the Dilly Beds. To what extent these resemblances are governed by facies differences cannot be ascertained at this stage.

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APPENDIX 3 : PLANT FOSSILS FROM THE SPRINGSURE SHEET AREA

by

Mary E. White

SUMMARY

Plant fossils were collected at 37 localities in the Springsure region of Queensland in 1963. The age of all but six of the fossil horizons could be determined on plant evidence.

The Joe Joe Formation, regarded by Shell (Queensland) Development Pty Ltd as Permian, was shown to be Carboniferous. The Mount Hall Conglomerate and the Ducabrook Formation contain Carboniferous Lepidodendron floras.

The Orion Shale contains Permian plants, and there is some evidence that it is of Lower Permian age. The Staircase Sandstone contains Lower Permian plants, and the Aldebaran Sandstone, Sirius Formation, and Stanleigh Formation have floras of general Permian type without any forms diagnostic of Upper or Lower Permian. The Colinlea Sandstone has a Lower Permian assemblage of plants.

The Blackwater Group and Black Alley Shale contain two species of Glossopteris regarded as indicative of Upper Permian age. Plants from six localities in the Blackwater Group and Black Alley Shale confirm an Upper Permian age for these units.

The Clematis Sandstone and the Moolayember Formation both contain plant assemblages which could be of Triassic or Jurassic age.

INTRODUCTION

Plant fossils were collected from 37 localities in the Springsure area of Queensland in 1963 by R.G. Mollan and party. At many of the localities the plants are well preserved and the specimens are of considerable interest. The localities have been arranged in stratigraphical order in the descriptions which follow. In some cases, field determination of formations has proved incorrect. Field locality numbers are shown in Plates 6, 7A, and 7B.

DESCRIPTIONS

1. Locality SP79: 2½ miles NNE of Telemon homestead. Silver Hills Volcanics. Specimens F22337.

Many indeterminate impressions of small stems are present. One lepidodendroid (decorticated) example shows features possibly of Protolepidodendron.

Age: Devonian(?)

2. Locality SP89/1: 4 miles W of Euneeke homestead. Mount Hall Conglomerate. Specimens F22339.

Stems of Lepidodendron veltheimianum Stbg. show many decortication forms as well as surface impressions.

Age: Carboniferous, probably Lower Carboniferous.

3. Locality SP80: 4 miles NNE of Telemon homestead. Ducabrook Formation(?). Specimens F22338.

These specimens contain many lepidodendroid stems, mostly decorticated, showing features of Lepidodendron. Lenticular leaf trace scars are arranged in ascending spirals. Many of the impressions are of very young stems.

There is a surface impression of a young stem, and a near-surface impression of a slightly older stem which shows that leaf base scars had rounded tops, pointed bases, and a median groove similar to that seen in Lepidodendron scutatum Lx. In the absence of a surface impression of a mature stem the species cannot be determined. The stems are of the same general type as L. veltheimianum Stbg.

Age: Carboniferous, probably Lower Carboniferous.

4. Locality SP56: Mistake Creek, about 10 miles NW of Telemon homestead. Telemon Formation.
Specimens F22402.

Decorticated lepidodendroid stem impressions with widely spaced lenticular leaf trace scars in an ascending spiral arrangement are referred to Lepidodendron sp. The species cannot be determined in the absence of surface impressions. Such decorticated forms occur in Upper Devonian as well as in Lower Carboniferous species, but not in Leptophloeum australe, which occurs in such profusion in the Telemon Formation.

Age: Carboniferous, or Upper Devonian(?)

5. Locality SP606: In Joe Joe Creek, immediately north of Joe Joe homestead, in NW corner of Springsure Sheet. Joe Joe Formation.
Specimens CPC7661 (Pl. B, fig. 1), CPC7662 (Pl. A, figs 1,2), F22323, F22330.

The specimens contain well preserved fern fronds of characteristic Carboniferous appearance, showing a range of forms from examples with separate pinnules of 'Rhacopteris meridionalis Feist.' type (Pl. B, fig. 1), through intermediate forms (Pl. A, fig. 1) to large foliose pinnae not divided into distinct pinnules of Cardiopteris polymorpha Goepp. type (Pl. A, fig. 2). It is clear from a study of all the specimens that all the pinna types seen in the collection are referable to one species. If the only specimen collected had been CPC7661, illustrated in Plate B, figure 1, this specimen would have been determined as Rhacopteris meridionalis Feist. Specimens in the collection of the Australian Museum, Sydney, referred to the species differ in no significant way from the frond in CPC7661. The presence of a range of intermediate types such as are illustrated in Plate A, figure 1, referable either to Rhacopteris or Cardiopteris, and of examples undeniably of 'Cardiopteris polymorpha Goepp.' (CPC7662) confirms that one species is involved.

Diversity of pinnule form is a well known phenomenon in Carboniferous ferns of this sort. Seward (Fossil Plants II) in discussing the problems of nomenclature arising from this diversity states that the name Ultopteris was suggested for ferns bearing Rhacopteris and Cardiopteris pinnae on the same plant. There is no valid separation in form from the genus Neuropteridium, and it has been decided by general consent to use the name Cardiopteris for Carboniferous examples and Neuropteridium for Mesozoic examples.

The name Cardiopteris polymorpha Goepp. is satisfactory for the specimens under discussion as it is descriptive of the diversity of form.

It seems likely, from the evidence in this collection, that Rhacopteris meridionalis Feist. may not be a valid species at all. In fact, some other species of Rhacopteris described from fragmentary specimens are possibly only diverse forms of Cardiopteris polymorpha Goepp.

In eastern Australia the Carboniferous rocks are distinguished as Lepidodendron and Rhacopteris types. These overlap stratigraphically, the former being dominant in Lower Carboniferous and the latter beginning in the upper part of Lower Carboniferous and attaining full development in the Upper Kuttung Beds and their equivalents.

Rhacopteris and Cardiopteris are recorded from many horizons in Australia including a Lower Carboniferous horizon at Stroud, NSW; Glacial stage of Kuttung Series, NSW; Upper Kuttung, NSW; Upper Carboniferous passage beds into Lower Bowen at Saint Helens in the Mackay-Proserpine region of Queensland; Silver Valley Series in Queensland; etc. It is thus impossible to differentiate between Upper and Lower Carboniferous on the presence of Rhacopteris.

Age: Carboniferous (Shell's tentative Permian age is incorrect. There is no instance of Rhacopteris from Permian beds.)

6. Locality SP608: 5 miles W of Joe Joe homestead. Joe Joe Formation.
Specimens F22325.

Indeterminate plant remains
Age: Indeterminate.

7. Locality SP609: 5 miles W of Joe Joe homestead. Joe Joe Formation.
Specimens F22326.

Equisetalean stems.
Age: Indeterminate

8. Locality SP311: 7½ miles W of Echo Hills homestead. Joe Joe Formation.
Specimens F22327.

Fragments of pinnules and rachis of Cardiopteris polymorpha Goepp. and equisetalean stems occur in these specimens.

Age: Carboniferous.

9. Locality SP301: 6½ miles S of Echo Hills homestead. Joe Joe Formation.
Specimens CPC7663, CPC7664.

In specimen CPC7663 a small frond of Cardiopteris polymorpha Goepp. is present on one side, and a large frond with Rhacopteris meridionalis type pinnules on the reverse. In specimen CPC7664, all the pinnules are of the latter type. In the light of evidence of the identity of the two forms at locality 606, all fronds are referred to Cardiopteris polymorpha.

Age: Carboniferous.

10. Locality SP352/2: 1 1/4 miles NW of Tresswell homestead. Ducabrook Formation.
Specimens F22331.

Equisetalean stems
Age: Indeterminate.

11. Locality SP354/1A: 1½ miles NW of Tresswell homestead. Ducabrook Formation.
Specimens F22334.

Equisetalean stems
Age: Indeterminate.

12. Locality SP374/1B: 2 miles SE of Nandowrie Needle. Probable Joe Joe Formation.
Specimens F22403.

A decorticated stem impression is the only plant fossil present. It appears to be lepidodendroid.

Age: Devonian or Carboniferous(?).

13. Locality SP41: 3 miles WSW of Mount Hall. Mount Hall Conglomerate.
Specimens F22332.

Stem impressions of all sizes are present. Most are indeterminate with irregular vertical striations. One shows decorticated lepidodendroid form of elongated leaf trace scars widely spaced. It appears to be referable to Lepidodendron, but is too deeply decorticated to be allocated to a species.

Age: Probably Carboniferous.

14. Locality SP363/4B: 2 miles W. of Connemarra homestead. Ducabrook Formation. Specimens F22391.

Lepidodendron veltheimianum Stbg. is identified in these specimens from surface impressions of young stems. There are many decortication forms present as well. Some ribbon-like impressions with a medium sulcus may represent large leaves of Lepidodendron, or may be stem impressions of the sort frequently found with Rhacopteris in Carboniferous horizons.

Age: Carboniferous.

15. Locality SP364/1: 1½ miles S. of Glenlee homestead. Ducabrook Formation. Specimens F22392.

A cast of a lepidodendroid stem is referred to Lepidodendron sp. An impression of a decorticated stem is indeterminate.

Age: Carboniferous.

16. Locality SP363/4A: 2 miles W. of Connemarra homestead. Reids Dome Beds. Specimens F22393.

Preservation of the fossils is poor. Leaves tentatively referred to Glossopteris indica Sch. and Glossopteris ampla Dana are present.

Age: Permian.

17. Locality SP4: 3 miles S.W. of Mount Sirius in a north branch of Orion Creek. Orion Formation.

Specimens F22335.

A large leaf of Glossopteris indica Sch. is associated with a fragment of leaf of Gangamopteris sp., whose presence suggests a Lower Permian age.

Age: Permian, probably Lower Permian.

18. Locality SP4A: 3 miles S.W. of Mount Sirius, in a north branch of Orion Creek. Orion Formation.

Specimens F22336.

Glossopteris sp.
Glossopteris scale leaf
Age: Permian.

19. Locality SP3: 2½ miles S.W. of Mount Sirius, in a north branch of Orion Creek. Orion Formation.

Specimens F22365.

A well preserved Glossopteris flora is present in these specimens. The venation is clearly shown. The following are identified:

Glossopteris communis Feist.
G. indica Sch.
G. angustifolia Brong.
G. stricta Bunb.
G. browniana Brong.
G. tortuosa Zeiller
Glossopteris scale leaves
Noeggerathiopsis hislopi Bunb.
Age: Permian, probably Lower Permian.

Note on the Age of the Orion Formation: Evidence from the plant fossils at localities SP4, SP4A, and SP3 for a Lower Permian age is somewhat meagre. A fragment of Gangamopteris venation at SP4 suggests Lower Permian, but at SP4A and SP3, plants of general Permian distribution occur. The Noeggerathiopsis hislopi Bunb. at SP3 is not of the coarse type restricted to Lower Permian.

20. Locality SP387/7: 3½ miles NW of Croydon Hills homestead. Staircase Sandstone. Specimens F22394.

Gangamopteris cyclopteroides Feist.
Glossopteris ampla Dana
Age: Lower Permian Gangamopteris cyclopteroides does not persist into Upper Permian.

21. Locality SP392/3: 2 miles W of Mount Kelman homestead. Aldebaran Sandstone. Specimens F22395.

Sulcate stems are present. They are indeterminate, but are of the same type as those which occur with Rhacopteris in Carboniferous floras.
Age: Indeterminate.

22. Locality SP112/1: Aldebaran Creek (south branch), about 3 miles E of Mount Catherine. Aldebaran Sandstone.
Specimens F22404.

Large numbers of impressions of Vertebraria indica Royle, some with numerous lateral appendages, are present.

Vertebraria indica occurs throughout the Permian, and there is nothing to indicate whether the specimens are Upper or Lower Permian.
Age: Permian.

Note on Aldebaran Sandstone: A Permian age is indicated by the plant fossils. There is no plant evidence for Lower Permian as the plant species present ranges throughout the Permian.

23. Locality SP392/4: 3 miles NW of Mount Kelman homestead. Sirius Formation. Specimens F22396.

Fragments of Glossopteris venation
Age: Permian. No indication whether Upper or Lower Permian.

24. Locality SP406/3: 2 miles S of Stanleigh homestead. Stanleigh Formation. Specimens F22397.

Equisetalean stems
Fragments of Glossopteris venation
Age: Permian. No plant evidence for Lower Permian.

25. Locality SP374/1A: 2 miles SE of Nandowrie Needle. Reids Dome Beds. Specimens F22405.

Vertebraria indica Royle
Gangamopteris cyclopteroides Feist.
?Glossopteris ampla Dana
Glossopteris indica Sch.
Age: Lower Permian.

26. Locality SP120: About 1 mile E. of Vandyke homestead. Colinlea Sandstone. Specimens F22406.

These specimens are poorly preserved. The following are identified:
Vertebraria indica Royle
Glossopteris indica Sch.
?Gangamopteris sp.
?Palaeovittaria sp.
Sphenopteris sp. pinnules
Age: Permian, Lower Permian(?)

27. Locality SP607: 5 miles W of Joe Joe homestead. Colinlea Sandstone.
Specimens F22324.

Glossopteris indica Sch.
Glossopteris angustifolia Brong.
Glossopteris scale leaf
Age: Permian. No indication whether Upper or Lower Permian.

28. Locality SP639: 3½ miles NW of Mantuan Downs homestead. Blackwater Group.
Specimens F22333.

Glossopteris communis Feist.
Glossopteris ampla Dana
Glossopteris taeniopteroides Feist.
Glossopteris conspicua Feist.
Equisetalean stems
Age: Upper Permian (on presence of G. conspicua and G. taeniopteroides).

29. Locality SP93: ½ mile S of Avoca homestead, in Freitag Creek. Blackwater Group.
Specimens F22340.

Glossopteris communis Feist.
Equisetalean stems
Phyllotheca etheridgei Arber, leaf whorls
Sphenopteris polymorpha Feist.
Part of small cone - probably equisetalean
Age: Permian, probably Upper Permian on the presence of Phyllotheca etheridgei.

30. Locality SP102: 4 miles SSW of Goathland homestead, in Cona Creek. Blackwater Group.
Specimens F22341.

These very coaly specimens contain the following plants:
Glossopteris conspicua Feist.
Glossopteris ampla Dana
Vertebraria indica Royle
Equisetalean stems
Age: Upper Permian.

31. Locality SP377/1: 1½ miles S of Kareela homestead. Blackwater Group.
Specimens F22398.

The plant remains in these specimens are fragmentary. The following are identified:
Glossopteris communis Feist.
Glossopteris conspicua Feist.
Glossopteris tortuosa Zeiller
Vertebraria indica Royle
Equisetalean stems
Age: Upper Permian.

32. Locality SP396/2: 3 3/4 miles ENE of Freitag homestead. Probably Black Alley Shale.
Specimens F22399.

Fragments of leaves of the following are present:
Glossopteris conspicua Feist.
Glossopteris ampla Dana
Glossopteris indica Sch.
Glossopteris parallela Feist.
Age: Upper Permian.

33. Locality SP396/4: 3½ miles ENE of Freitag homestead. Probably Black Alley Shale.
Specimens F22400, CPC7665.

Fragments of leaves of Glossopteris conspicua Feist. and Glossopteris indica Sch. are associated with equisetalean stems. There are also three foliar organs which are believed to be fertile male scale fronds of Glossopteris type. Two of these are illustrated in Plate B, figure 2 (specimen CPC7665). They were apparently flat, thin, leaf-like structures. Each has elongated narrow depressions following the gangamopteroid venation pattern. The depressions are believed to represent sporangia.
Age: Upper Permian.

34. Locality SP713: Reids Dome, Mitchell Creek, a mile above the junction with Rocky Creek. Blackwater Group.
Specimens F22407, F22408, F22409.

Beautifully preserved leaves of the following species of Glossopteris are present:
Glossopteris conspicua Feist.
Glossopteris communis Feist.
Glossopteris angustifolia Brongn.
Glossopteris indica Sch.
Glossopteris damudica Feist.

Obscure fructification (CPC7666): A thin stalk 1.5 cm long and 0.15 cm wide has an expanded head with four lobes. Each has a raised rib along its centre. The lobes are blunt. No reliable guess can be made as to the nature of this specimen.
Age: Upper Permian.

Note on the Age of the Black Alley Shale and Blackwater Group: Evidence from the plant fossil collections confirms an Upper Permian age for the Black Alley Shale and the Blackwater Group.

35. Locality SP160: At base of Mount Carnarvon. Clematis Sandstone.
Specimens F22410.

Equisetalean stems
Age: Indeterminate.

36. Locality SP508: 7 miles S of Consuelo homestead, Rewan Syncline. Clematis Sandstone.
Specimens CPC7667, F22412.

In specimen CPC7667 (Pl. C) two magnificent fronds of Dicroidium odontopteroides (Morr.) Gothan are present. Carbonized cuticular material covers the impression surface and preparations of cuticles will be made in due course for microscopic examination. Specimens F22412 contain equisetalean stems and small fragments of Dicroidium odontopteroides. Dicroidium odontopteroides ranges from Middle Triassic to Middle Jurassic.
Age: Triassic or Jurassic.

Note on the Clematis Sandstone: On plant evidence a Triassic or Lower Jurassic age is indicated.

37. Locality SP664: 30 miles S of Mantuan Downs homestead. Moolayember Formation.
Specimens F22413.

Pterophyllum nathorsti (Seward)
Dicroidium odontopteroides (Morr.) Gothan
Pterophyllum abnorme Eth. fil.
?Sphenopteris superba Shirley
Dicroidium coriacium (Johnst.) Townrow

Dicroidium odontopteroides occurs in Triassic and Lower Jurassic. *Dicroidium coriacium* occurs in the Ipswich Series in Queensland and in Triassic of Tasmania etc. *Pterophyllum nathorsti* and *P. abnorme* occur in the Walloon Series in Queensland.

Age: Triassic or Jurassic.

Note on Moolayember Formation: There is no plant evidence in this collection to limit the Moolayember Formation to Triassic. It could equally well be Lower Jurassic.

PLATE A

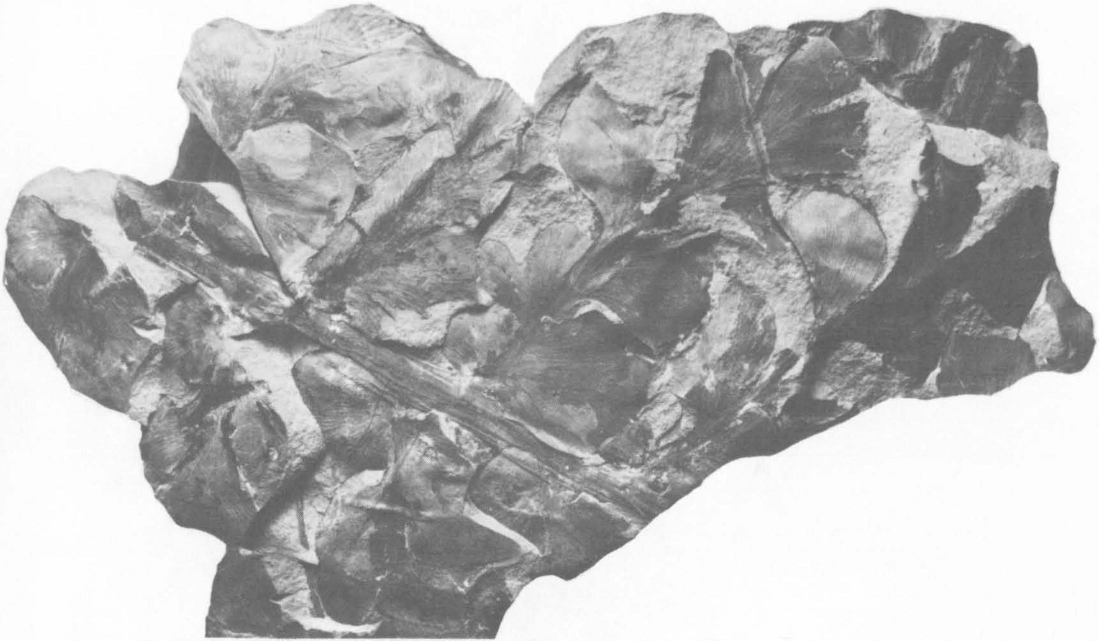


Fig. 1. Cardiopteris palymorpha Goepp. Intermediate type pinnicles. CPC7622. (Natural size).

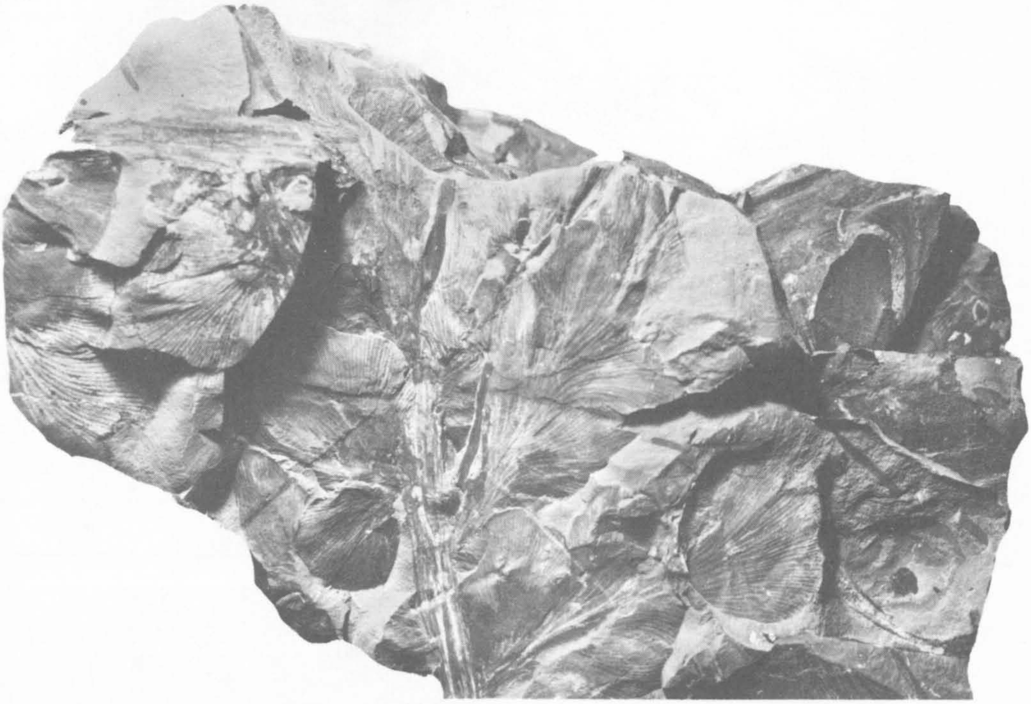


Fig. 2. Cardiopteris polymorpha Goepp. C. polymorpha Goepp. type frond. CPC7662. (Natural size).

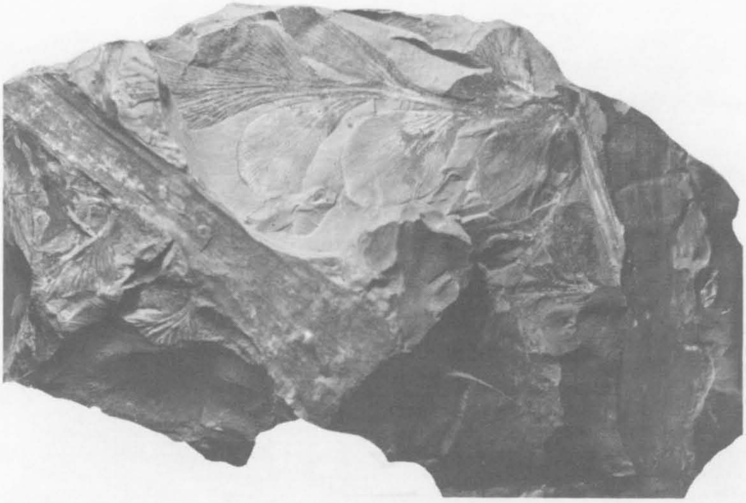


Fig. 1. Cardiopteris polymorpha Goepp. Pinnicles of Rhacopteris meridiovalis Feist. type. CPC7661. (Natural size).

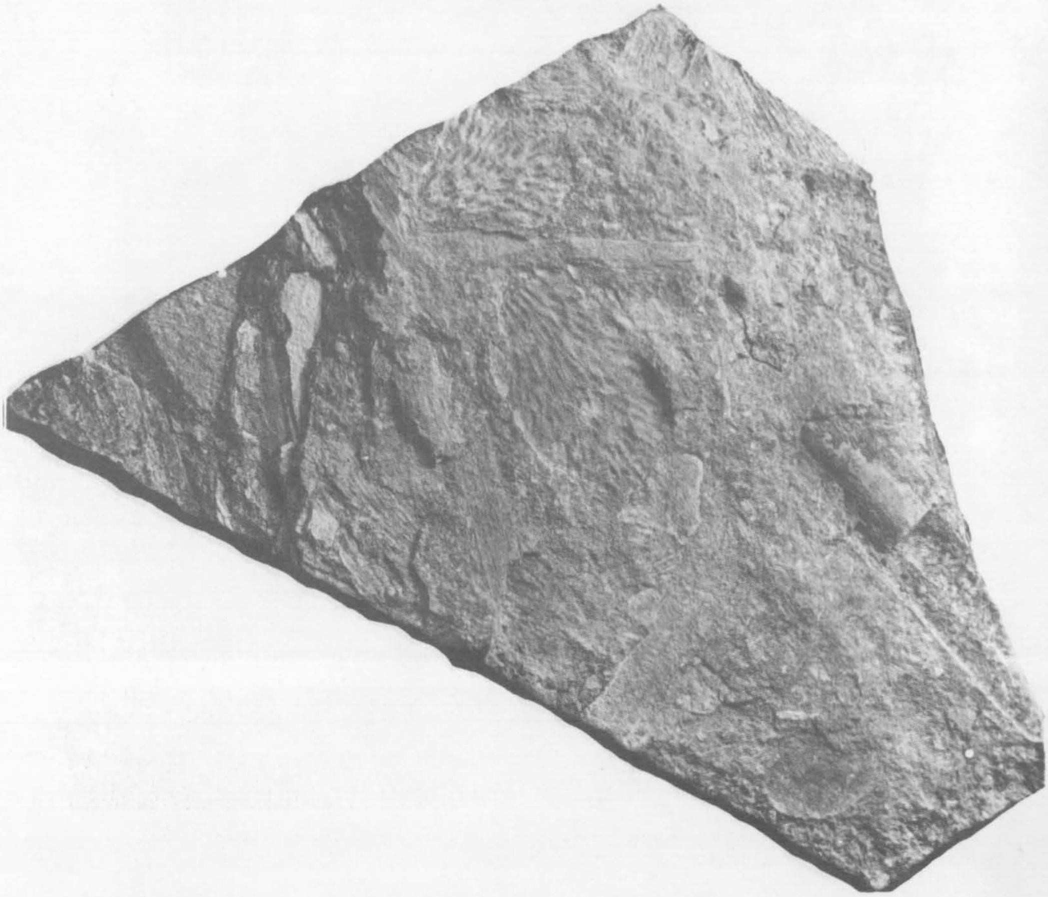
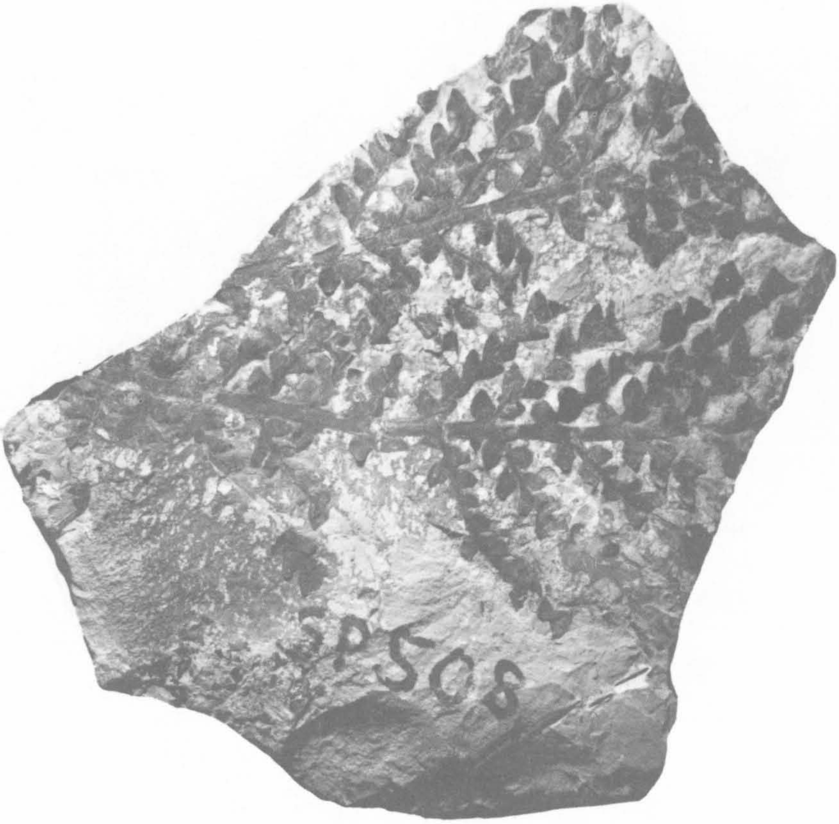


Fig. 2. Clossopteris sp. Fertile male scale fronds. CPC7665. (X2).

PLATE C



Dicroidmiu odoutopteroides (Marr.) Catlian. CPC7667. (X 1/4)

APPENDIX 4: PRELIMINARY REPORT ON A COLLECTION OF CORALS FROM PEBBLES IN CONGLOMERATES IN THE JOE JOE FORMATION

by

Dorothy Hill

Locality SP360/5*:	$2\frac{1}{2}$ miles NNW of Riverside homestead.
	Favositidae, slenderly branching, genus and species indeterminable. *Atrypa* and other brachiopods; returned for determination at the Geological Survey of Queensland.
Locality SP360/6:	$2\frac{1}{2}$ miles NNW of Riverside homestead.
	Favostella (Dendrostella) cf. *rhenana* (Frech)
Locality SP600:	7 miles NE of Joe Joe homestead.
1a	*Litophyllum konincki* (Etheridge & Foord) and stromatoporoid
1b	*Alveolites* sp. *Litophyllum konincki*. *Grypophyllum* sp. Stromatoporoids
1c	*Rugosa* solitary, gen. et sp. nov.? (insufficient material; retained for further study)
2	New branching favositid. Slide and piece of specimen retained for further study
3	Favositidae. Indeterminable
4	*Favostella (Dendrostella)* cf. *rhenana* (Frech) *Amphipora ramosa* Branching stromatoporoid
5	*Litophyllum konincki* (Etheridge & Foord)
6	*Rugosa*, small, solitary, indeterminable: a. ?*Cladopora* sp. b. ?*Cladopora* sp. and Rugosa, small, solitary, dissepimented, indeterminable

The pebbles from SP360 and SP600 are derived from Middle Devonian limestones. None of the coral species represented is quite identical with any of those I have previously reported from the Springsure, Emerald, and Clermont 1:250,000 Sheet areas for the BMR/GSQ parties.

Favostella cf. *rhenana* Frech. and *Grypophyllum* sp. are present in some pebbles from the Joe Joe Formation collected by Shell (Qld) Development Pty Ltd which, in 1942, I suggested might be derived from upper Middle Devonian limestones. *Litophyllum konincki* in addition to the above two species occurs in the present collections and adds some support to this view. However, no upper Middle Devonian limestones crop out on the map areas. *Litophyllum konincki* with thinner walls is known from the lower Middle

---

* Localities are shown in Plate 6.

Devonian limestones cropping out on the above map areas, and *Favostella* (*Dendrostella*) *prerhenana* Glinski, a species closely related to *F. rhenana*, occurs in the lower Middle Devonian of the Eifel, and it is not impossible for all the pebbles to have been derived from lower Middle Devonian limestones.

The specimens and slides, except from SP600/1c and SP600/2, have been returned to the Geological Survey of Queensland.

APPENDIX 5: CONODONTS FROM AMOSEAS SAMPLE HEQ-76B, SPRINGSURE 1:250,000 SHEET AREA

by

E.C. Druce

A sample from 24°19'15"S., 147°39'30"E. yielded a fauna of nine specimens, eight of which belong to the genus Icriodus. The following species were identified:

Icriodus nodosus (Huddle)
Spathognathodus bipennatus (Bischoff & Ziegler)

This fauna is of Devonian age. Icriodus nodosus ranges from the base of the Eifelian into the Frasnian. Spathognathodus bipennatus is restricted to the Sparganophyllumkalk of the Ober Stringocephalen Stufe of Middle Devonian (Givetian) age. Specimens referred to S. cf. bipennatus have been discovered in Eifelian strata. The age of the sample is thus upper Middle Devonian (Givetian), though a lower Middle Devonian (Eifelian) age cannot be precluded.

APPENDIX 6: WATERBORES

Waterbores shown in Plate 6 are listed here. Borehole data are listed in Table 3 of Mollan, Exon, & Kirkegaard (1964). The 'B' numbers were introduced by us; the 4-digit numbers are registered numbers of the Irrigation and Water Supply Commission.

No.	Name
B1	Mantuan Downs No. 15 (Bletsoe)
B2	Lower Canopus
B3	Wealwandangie homestead
B4	Dalmally No. 1
B5	Freitag No. 2
B6	Orion Park homestead
B7	MacQueens
B8	Shed
B9	Four Mile Yards
B10	One Mile
B11	Aldebaran
B12	New Five Mile
B13	Lower Springs
B14	Heifer Paddock No. 2
B15	Gibbs No. 2
B16	Patens
B17	New Slip
B18	Shelleys
B19	No. 1 (Rat Hill)
B20	Stoney No. 2
B21	Kurrajong
B22	Bottle Tree Plain
B23	Boomerang
B24	Coynes
B25	Washpool
B26	Top Eight Mile
B27	Rocky
B28	Bullock Paddock
B29	Bonnyboys
B30	Ingelara homestead
B31	Albinia Downs homestead
B32	Sandy Creek
3498	Mantuan Downs No. 12 (Hobblers)
8496	" " No. 9 (Johnnys)
8497	" " No. 10 (Letter Box)
8499	" " No. 14 (Box Creek)
9783	" " No. 1 (Houce)
9784	" " No. 2 (Avenue)
9785	" " No. 3 (Double Tank)
9786	" " No. 4
9787	" " No. 5 (Bay of Biscay)
9788	" " No. 6
9789	" " No. 7 (Engine Well)
8790	" " No. 8 (Maori Gully)
9793	" " No. 16 (Spring Tank)

APPENDIX 7: K-Ar AGE DETERMINATIONS

by

A.W. Webb

Sample No.	Rock Type	Locality	Sample Dated	K-Ar Age ($x10^6$yrs)	Remarks
GA5194	Muscovite-garnet schist	Core of Telemon Anticline (24°19'S, 147° 32'E.)	Muscovite	351, 353	The indicated minimum age of the granodiorite is Upper Ordovician (Kulp, 1961). This age conflicts with the younger date measured on the schist (GA5194) a few miles to the south (Upper Devonian/Lower Carboniferous, McDougall et al., 1966)
GA1039	Granodiorite	Core of Telemon Anticline (24°07'S., 147° 32'E.)	Biotite Hornblende	445, 444 452	If the metamorphism occurred 350 million years ago, its effects should be apparent in the K-Ar mineral ages and texture of the granodiorite. However, specimen GA1165 is massive and shows no signs of having undergone metamorphism since the Upper Ordovician. The significance of the muscovite age is not known
GA1039	Basalt	Southeast of Rooken Glen homestead (24°05'S., 147°32'E.)	Plagioclase	293	This is a minimum age. The plagioclase is altered and unsuitable for dating. The determination was made to investigate the possibility of a Tertiary age for this basalt. The result shows that this sample must be Upper Carboniferous or older.

Sample No.	Rock Type	Locality	Sample Dated	K-Ar Age ($x10^{6}$yrs)	Remarks
GA1031	Olivine basalt	Springsure-Tambo road ($24^{0}07\frac{1}{2}$'S., $147^{0}56\frac{1}{2}$E.)	Whole rock	26.8	With the exception of GA1032, the results are internally consistent and indicate that the lavas were extruded between 28 and 26.5 million years ago (Upper Oligocene, Funnell, 1964)
GA1032	Olivine basalt	Springsure-Tambo road ($24^{0}08$'S., $147^{0}57\frac{1}{2}$'E.)	Whole rock	24.0, 23.2	
GA1033	Olvine basalt	($24^{0}01$'S., $148^{0}03$'E.)	Whole rock	27.7	
GA1034	Olvine basalt	($24^{0}01$'S., $148^{0}03$'E.) Overlies GA1033	Whole rock	26.7	
GA1035	Olvine basalt	Mt Boorambool. Overlies GA1036 ($24^{0}06$'S., $148^{0}04$'E.)	Whole rock	27.0	
GA1036	Basalt	Mt Boorambool ($24^{0}06$'S., $148^{0}04$'E.)	Whole rock	27.5	
GA1149	Trachyte	Red Hill ($24^{0}00\frac{1}{2}$'S., $148^{0}06\frac{1}{2}$'E.)	Sanidine	25.9	These ages support the conclusion reached from field and petrographic studies that the trachyte intrusions and basalt flows are closely related in age
GA1150	Trachyte	Red Hill ($24^{0}00\frac{1}{2}$'S., $148^{0}06\frac{1}{2}$'E.)	Sanidine	26.3	

Decay constants used: B $=4.72x10^{-10}$ yr^{-1}; $=0.584x10^{-10}$ yr^{-1}; $^{40}K = 1.22x10^{-4}$ g/g K

All analytical work was carried out in the Department of Geophysics and Geochemistry, Australian National University.

Analytical precision is ± 3 percent.

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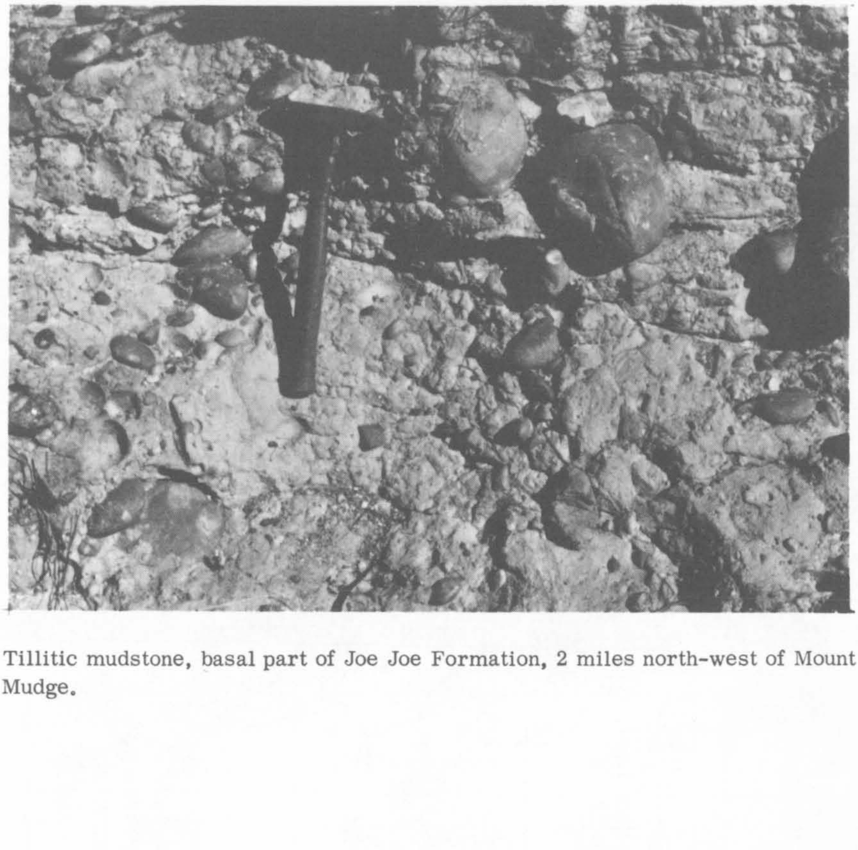
KULP, J.L., 1961- Geologic time scale. Science, 133, 1105-14.

McDOUGALL, I., COMPSTON, W., and BOFINGER, V.M., 1966 - Isotopic age determinations on Upper Devonian rocks from Victoria, Australia: a revised estimate for the age of the Devonian-Carboniferous boundary. Bull. geol. Soc. Amer., 77, 1075-88.

PLATE 1



Tillitic mudstone, basal part of Joe Joe Formation, 2 miles north-west of Mount Mudge.

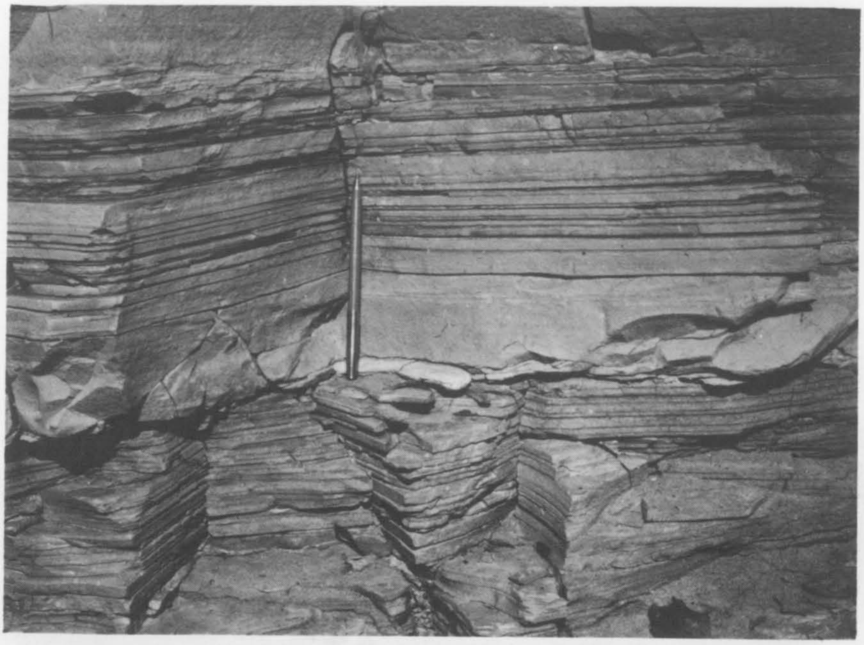


Fig. 1. Varved lutite, upper part of Joe Joe Formation, 4 miles south of Joe Joe Homestead.

Fig. 2. Striated and faceted boulder from the Joe Joe Formation, 3 miles north of Joe Joe Homestead.

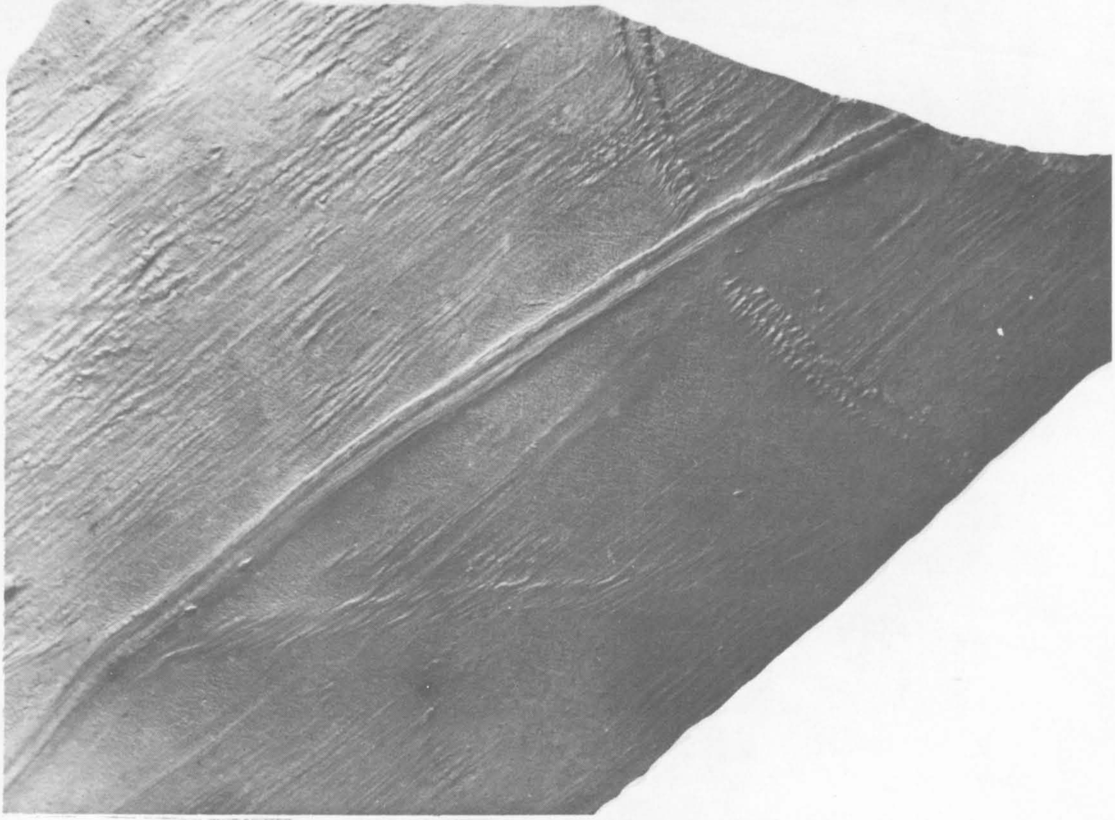


PLATE 3

Fig. 1. Animal tracks (arthropods?) and current striates on lower surface of siltstone bed, Joe Joe Formation. (Natural scale).

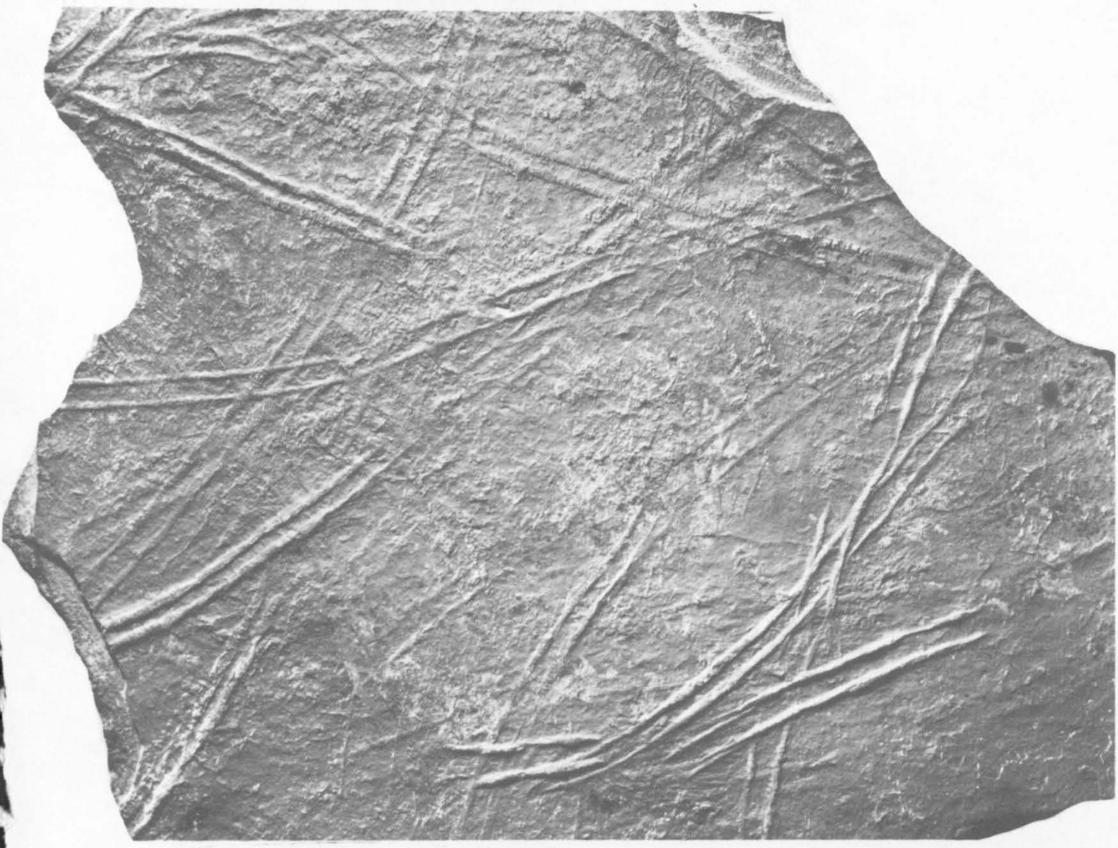


Fig. 2. Animal tracks (arthropods?) in the lower surface of a siltstone bed in the Joe Joe Formation. (Natural scale).

Fig. 1. Large boulder embedded in poorly sorted dark grey sandy conglomeratic siltstone, Cattle Creek Formation, Cattle Creek, Reids Dome.

Fig. 2. Silicified log, basal part of Blackwater Group, about half a mile north of Buckland Plains Homestead.

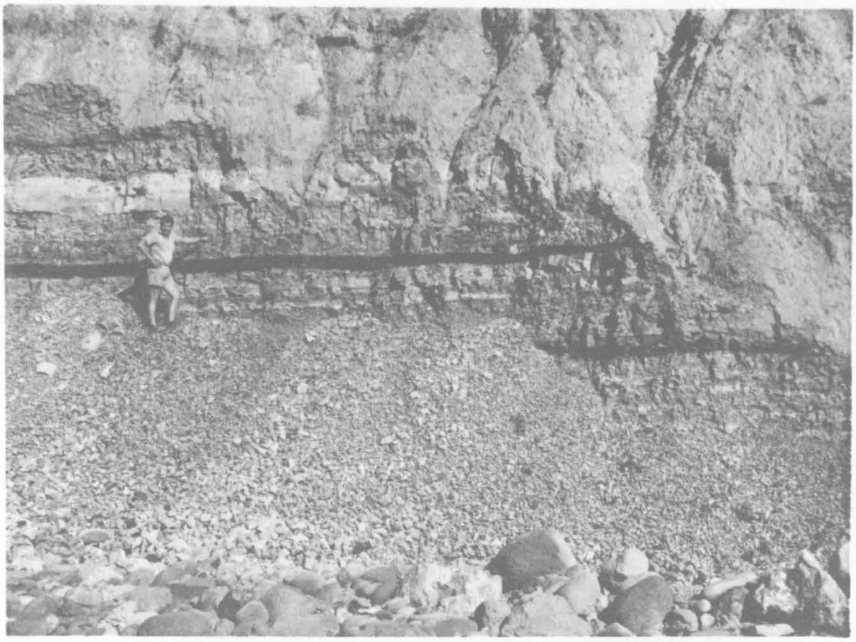


Fig. 1. Thin seams of coal in interbedded sandstone and siltstone, Blackwater Group, in Spring Creek, about 4 miles south of Kareela Homestead.

Fig. 2. Major fault defined by numerous dykes and domes of the Minerva Hills Volcanics. St Peter in centre background. (Looking north-west).

PLATE 6

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

SPRINGSURE
QUEENSLAND

SHEET SG 55-3

Reference

	Geological boundary
	Anticline, showing plunge
	Syncline, showing plunge
	Fault (D - downthrown side)
	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
	Unmeasured dip
	Vertical strata
	Horizontal strata
	Generalised strike and dip of undulating strata
	Strike and dip of foliation
	Dip < 5° } air-photo interpretation
	Dip 5°-15° } air-photo interpretation
	Dip 15°-45° } air-photo interpretation
	Dip > 45° } air-photo interpretation
	Horizontal strata } air-photo interpretation
	Dip slope < 15° } air-photo interpretation
	Bedding trend lines } air-photo interpretation
	Jointing } air-photo interpretation
ov	Basalt plug
	Dyke: r - rhyolite, b - basalt
•M	Mantuan *Productus* Bed outcrop
	Macrofossil locality
e	Macrofossils in erratics
	Plant fossil locality
	Fossil wood locality
	Fossil locality, general (algae, fish scales, megaspores)
SP 647	Fossil locality numbers
•C	Coal outcrop
	Dry oil well (abandoned)
	Abandoned well with show of gas
	Abandoned well with show of oil and gas
	Gas well
B.M.R.No5	Shallow stratigraphic drill hole
	Measured type-section
	Measured section
	Where dashed, section transferred along strike
S6	Measured section reference number
○	Bore
	Subartesian bore
□	Well
	Windpump
□E	Tank
9786	I.W.S. registered bore number
B25	Bore reference number
	Spring
	Swamp
	Road
	Vehicle track
	Railway with station
"Euneeke" HS	Homestead
	Landing ground
□yd	Stockyards
·920′	Height in feet, barometric } datum: mean sea level
·1066′	Height in feet, instrument levelled } datum: mean sea level
○ 4/5052	Air photo centre point - run/number

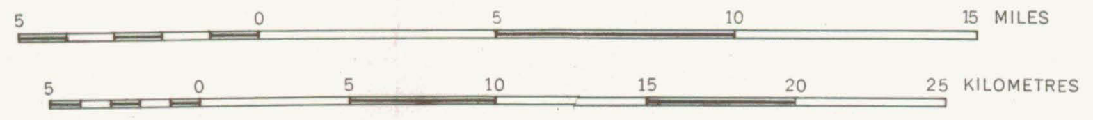
Reference

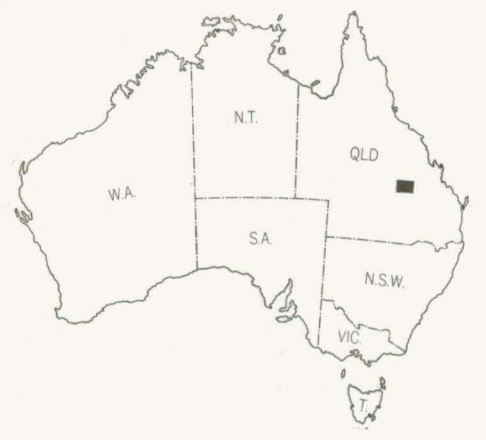
CAINOZOIC	QUATERNARY		Qa	Alluvium
			Cz	Soil, gravel, scree, alluvium
	TERTIARY			Laterite
			Ta	Conglomerate, sandstone, clay
			Tc	Collapsed sheets of basalt
		Minerva Hills Volcanics	Tr	Plugs, domes, and dykes of alkaline quartz trachyte and rhyolite
			Tb	Basaltic flows, minor pyroclastics, and sediments
MESOZOIC	MIDDLE JURASSIC	Birkhead Formation	Jmb	Lithic sandstone, siltstone, shale, coal
	LOWER JURASSIC	Hutton Sandstone	Jlh	Feldspathic quartz sandstone
		Westgrove Ironstone Member	Jlw	Concretionary ironstone, ferruginous siltstone, shale
		Boxvale Sandstone Member	Jlb	Quartz sandstone, siltstone, minor coal
		Evergreen Formation	Jle	Lithic sandstone, shale, minor coal
		Precipice Sandstone	Jlp	Cross-bedded pebbly quartz sandstone
	TRIASSIC	Mimosa Group: Moolayember Formation	Rm	Lithic sandstone, siltstone, shale
		Mimosa Group: Clematis Sandstone	Re	Cross-bedded pebbly quartz sandstone, siltstone
		Rewan Formation	Rr	Red and green silty mudstone, lithic quartz sandstone
		Brumby Sandstone Member	Rb	Pebbly lithic sandstone
PALAEOZOIC	UPPER PERMIAN	Blackwater Group (='upper part of Bandanna Formation')	Puw	Lithic sandstone, siltstone, shale, coal
		Blenheim Sub-group: Black Alley Shale	Puc	Black shale, soft clay, tuff
		Blenheim Sub-group: Peawaddy Formation	Pup	Lithic quartz sandstone, carbonaceous siltstone lenticular coquinite (Mantuan *Productus* Bed)
	LOWER PERMIAN	Back Creek Group, Gebbie Sub-group: Catherine Sandstone	Plf	Feldspathic quartz sandstone
		Ingelara Formation	Pli	Conglomeratic siltstone, sandy mudstone, calcareous shelly concretions
		Aldebaran Sandstone	Pll	Cross-bedded conglomeratic quartz sandstone, siltstone, minor coal
		Colinlea Sandstone	Plo	Cross-bedded conglomeratic quartz sandstone, minor siltstone
		Back Creek Group, Tiverton Sub-group: Sirius Formation	Pls	Pebbly siltstone, shale, sandstone, minor coal
		Staircase Sandstone	Plt	Cross-bedded conglomeratic quartz sandstone, siltstone, shale
		Stanleigh Formation	Plh	Lithic quartz sandstone, dark shale, siltstone, minor limestone
		Cattle Creek Formation	Plk	Conglomeratic siltstone, sandy mudstone, sandstone, coquinitic limestone
		Reid's Dome Beds: Orion Formation	Plg	Lithic quartz sandstone, carbonaceous shale
		Reid's Dome Beds	Plj	Sandstone, siltstone, shale, coal
	CARBONIFEROUS - PERMIAN ?	Joe Joe Formation	C-Pj	Lithic conglomerate, lithic quartz sandstone, siltstone, minor shale
	LOWER CARBONIFEROUS	Ducabrook Formation	Clu	Lithic sandstone, siltstone, red and green shale, tuff, minor algal limestone
		Raymond Sandstone	Clr	Flaggy quartz sandstone, minor siltstone
		Mount Hall Conglomerate	Clh	Cross-bedded conglomeratic quartz sandstone
	UPPER DEVONIAN - LOWER CARBONIFEROUS ?	Telemon Formation	Dut	Lithic conglomerate and sandstone, multicoloured tuffaceous siltstone and shale, algal limestone
	UPPER DEVONIAN ?	Silver Hills Volcanics	Ds	Intermediate, basic, and acidic volcanics, conglomerate, sandstone, shale.
	SILURIAN ? - DEVONIAN	Dunstable Volcanics	Dn	Tough, green, andesitic lavas and pyroclastics, splintery shale, lenses of coralline limestone.
	LOWER PALAEOZOIC ?		Pzg	Granite
		Anakie Metamorphics	Pza	Schist, phyllite, sheared diorite, gneiss.

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Queensland. Slotted templates supplied by the Division of National Mapping, Department of National Development. Aerial photography by Adastra Airways Pty.Ltd.; complete vertical coverage at 1:85,000 scale. Transverse Mercator Projection.

Geology and compilation, 1963-64, by R.G.Mollan, N.F.Exon, (B.M.R.), and A.G.Kirkegaard, (G.S.Q.).
Drawn by E.H.J.Feeken

Scale 1 : 250,000





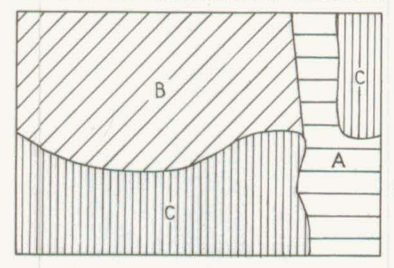
INDEX TO ADJOINING SHEETS
Showing Magnetic Declination

MUTTABURRA SF 55-9	GALILEE SF 55-10	CLERMONT SF 55-11	SAINT LAWRENCE SF 55-12	PORT CLINTON SF 56-9
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

9°E 8°30′E 8°E

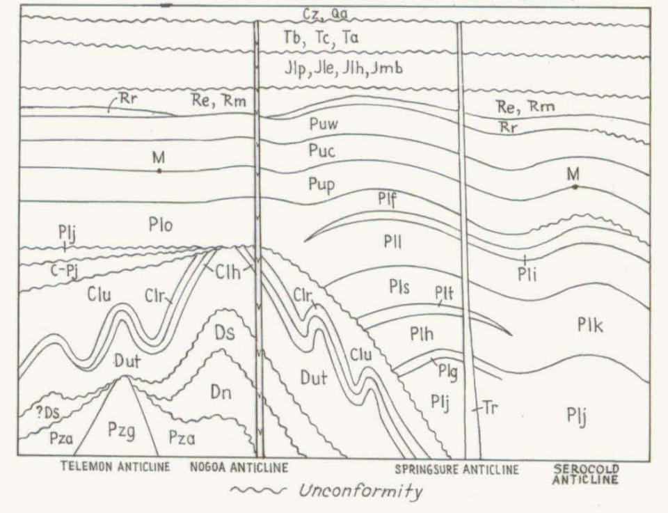
ANNUAL CHANGE 3′E

GEOLOGICAL RELIABILITY DIAGRAM

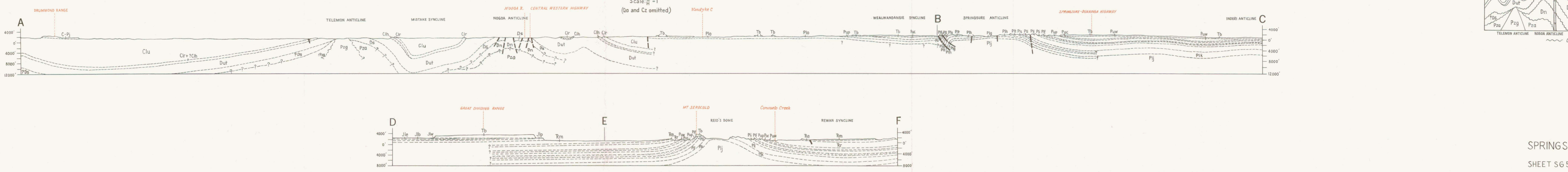


A Detailed mapping
B Detailed reconnaissance - numerous traverses
C Reconnaissance - several traverses

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Sections
Scale: $\frac{V}{H} = 1$
(Qa and Cz omitted)



SPRINGSURE
SHEET SG 55-3

Plate 7A

GEOLOGY OF THE SPRINGSURE, SEROCOLD, AND CONSUELO ANTICLINES

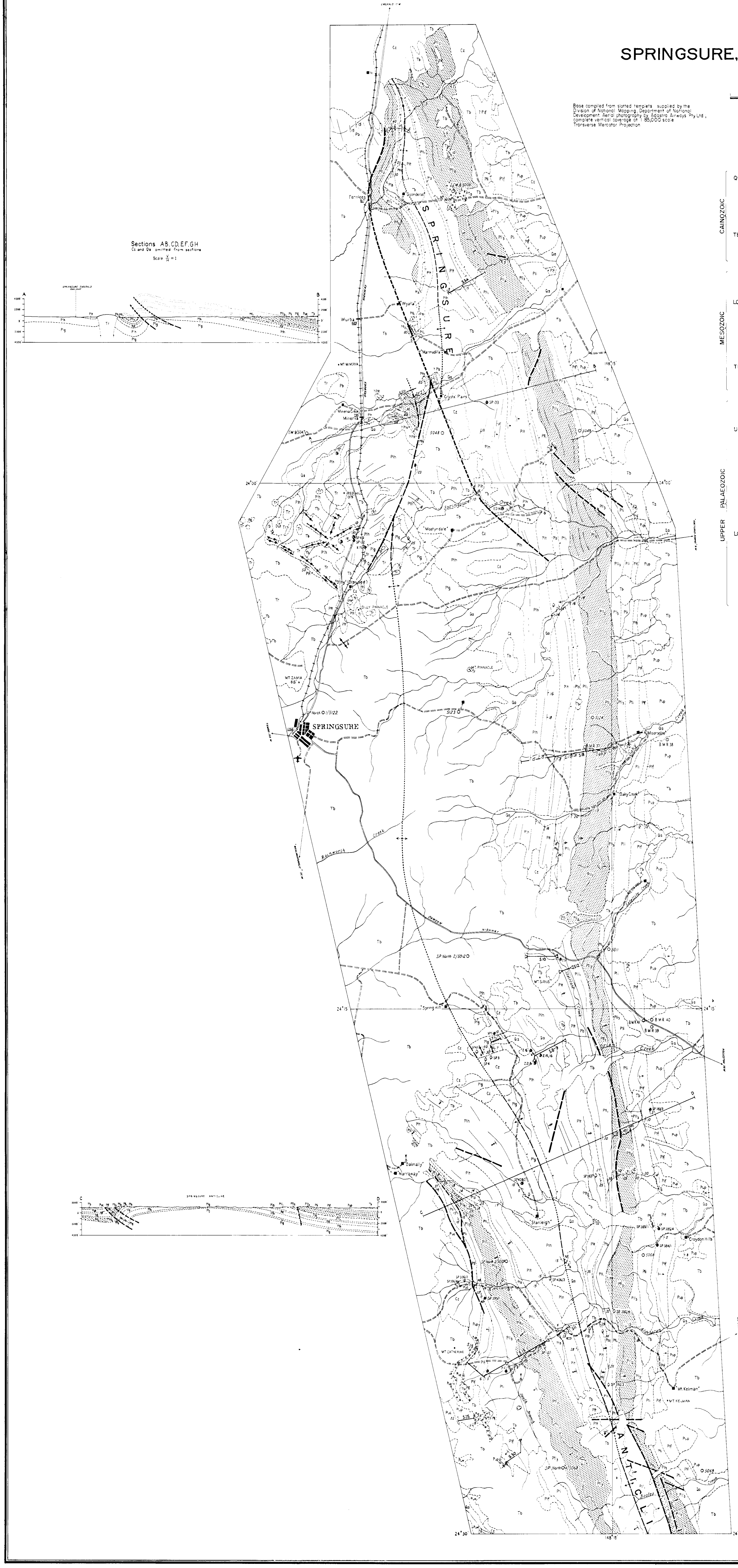
Scale

1 0 1 2 3 4 5 6 7 Miles

Base compiled from slotted templets supplied by the Division of National Mapping, Department of National Development. Aerial photography by Adastra Airways Pty. Ltd., complete vertical coverage at 1:85,000 scale
Transverse Mercator Projection

Geology and compilation, 1964-65 by: R.G. Mollan, N.F. Exon (BMR)
and A.G. Kirkegaard (G.S.Q.)
Drawn by: E.H.J. Feeken and I. Chertok

Sections AB, CD, EF, GH
Cz and Qa omitted from sections
Scale $\frac{V}{H} = 1$



Reference

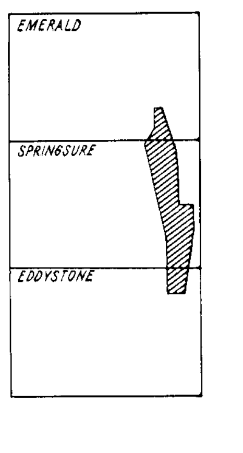
				Symbol	
CAINOZOIC	QUATERNARY			Qa	*Alluvium*
				Cz	*Soil, gravel, scree, alluvium*
	TERTIARY			⁘	*Laterite*
				Ta	*Conglomerate, sandstone, clay*
		Minerva Hills Volcanics		Tr	*Plugs, domes, and dykes of alkaline quartz trachyte and rhyolite*
				Tb	*Basaltic flows, minor pyroclastics, and sediments*
MESOZOIC	LOWER JURASSIC	Hutton Sandstone		Jlh	*Feldspathic quartz sandstone*
		Westgrove Ironstone Member		Jlw	*Concretionary ironstone, ferruginous siltstone, shale*
		Boxvale Sandstone Member		Jlb	*Quartz sandstone, siltstone, minor coal*
		Evergreen Formation		Jle	*Lithic sandstone, shale, minor coal*
		Precipice Sandstone		Jlp	*Cross-bedded pebbly quartz sandstone*
	TRIASSIC	Mimosa Group	Moolayember Formation	Rm	*Lithic sandstone, siltstone, shale*
			Clematis Sandstone	Re	*Cross-bedded pebbly quartz sandstone, siltstone*
			Rewan Formation	Rr	*Red and green silty mudstone, lithic quartz sandstone*
			Brumby Sandstone Member	Rb	*Pebbly lithic sandstone*
UPPER PALAEOZOIC	UPPER PERMIAN	Blackwater Group	(Upper part of Bandanna Formation)	Puw	*Lithic sandstone siltstone, shale, coal*
			Undifferentiated	Pb	*Lithic sandstone*
			Black Alley Shale	Puc	*Black shale, soft clay, tuff*
			Peawaddy Formation	Pup	*Lithic quartz sandstone, carbonaceous siltstone, lenticular coquinite (Mantuan Productus Bed)*
	LOWER PERMIAN	Back Creek Group	Catherine Sandstone	Plf	*Feldspathic quartz sandstone*
			Ingelara Formation	Pli	*Conglomeratic siltstone, sandy mudstone, calcareous shelly concretions*
			Aldebaran Sandstone: *transition member*	Pll₃	*Thinly interbedded siltstone and sandstone*
			Aldebaran Sandstone: *conglomerate member*	Pll₂	*Conglomeratic quartz sandstone*
			Aldebaran Sandstone: *sandstone member*	Pll₁	*Feldspathic quartz sandstone*
			Sirius Formation	Pls	*Pebbly siltstone, shale, sandstone, minor coal*
			Staircase Sandstone	Plt	*Cross-bedded conglomeratic quartz sandstone, siltstone, shale*
			Stanleigh Formation	Plh	*Lithic quartz sandstone, dark shale, siltstone, minor limestone*
			Cattle Creek Formation	Plk	*Conglomeratic siltstone, sandy mudstone, sandstone, coquinitic limestone*
		Reids Dome Beds	Orion Formation	Plg	*Lithic quartz sandstone, carbonaceous shale*
				Plj	*Sandstone, siltstone, shale, coal*

Geological boundary
Anticline, showing plunge
Syncline, 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
Unmeasured dip
Horizontal strata
Dip < 5°
Dip 5°–15°
Dip 15°–45°
Dip > 45°
Horizontal strata
Bedding trend-lines
Jointing
(from *Dip < 5°* to *Jointing*:) *air-photo interpretation*
Basalt plug
Dyke: r-rhyolite, b-basalt

·M	*Mantuan Productus Bed outcrop*
	Macrofossil locality
	Plant fossil locality
	Fossil wood locality
SP 132 Z 75 ED 141	*Fossil locality numbers*
· C	*Coal outcrop*
· OI	*Oil shale outcrop*
	Dry well (abandoned)
	Abandoned well with show of gas
	Abandoned well with show of oil and gas
⊙ B M R 41	*Shallow stratigraphic drill hole*
	Measured type section
	Measured section, where broken line transfer along strike
S 8	*Measured section reference number*
	Bore with windmill
▢ E	*Tank*
	Swamp
	Road
	Vehicle track
	Railway with station and siding
■ "Consuelo" ■	*Homestead*
	Landing ground
▢ yd	*Stockyards*
· 1066′	*Height in feet, instrument levelled* } *datum: mean sea level*
· 1815′	*Height in feet, barometric* } *datum: mean sea level*
OEM 9/5047	*Air-photo centre point - run/number*

1:250,000 Sheet Index



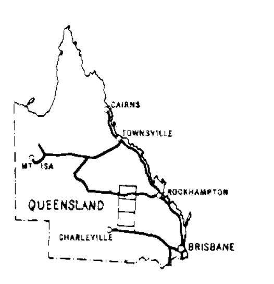
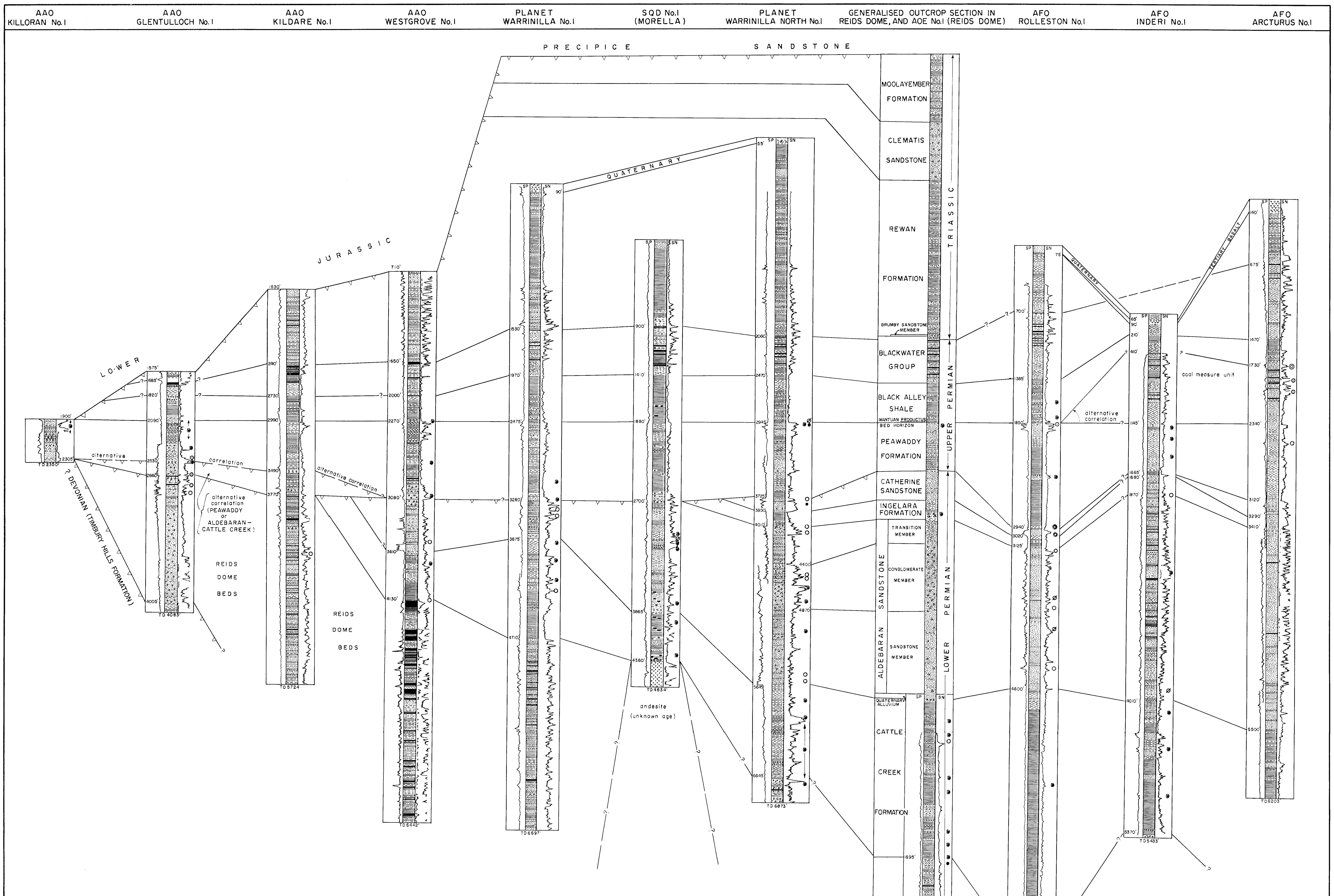


Plate 7B

24°30'
148°15'
24°45'
25°00'
SEROCOLD
ANTICLINE
REIDS DOME
Sandy Creek
Yellowbank Creek
Peawaddy Creek
Consuelo Creek
Rocky Creek
Carnarvon Creek
"Springwood"
"Peawaddy"
"Consuelo"
"Aldinga Park"
"Serocold"
"Rewan"
"Early Storms"
"Bandanna"
MT SEROCOLD
MT CARNARVON
MT NELLIS
SNAKE HILL
REIDS DOME
CONSUELO ANTICLINE
E
F
G
H

PLATE 8A



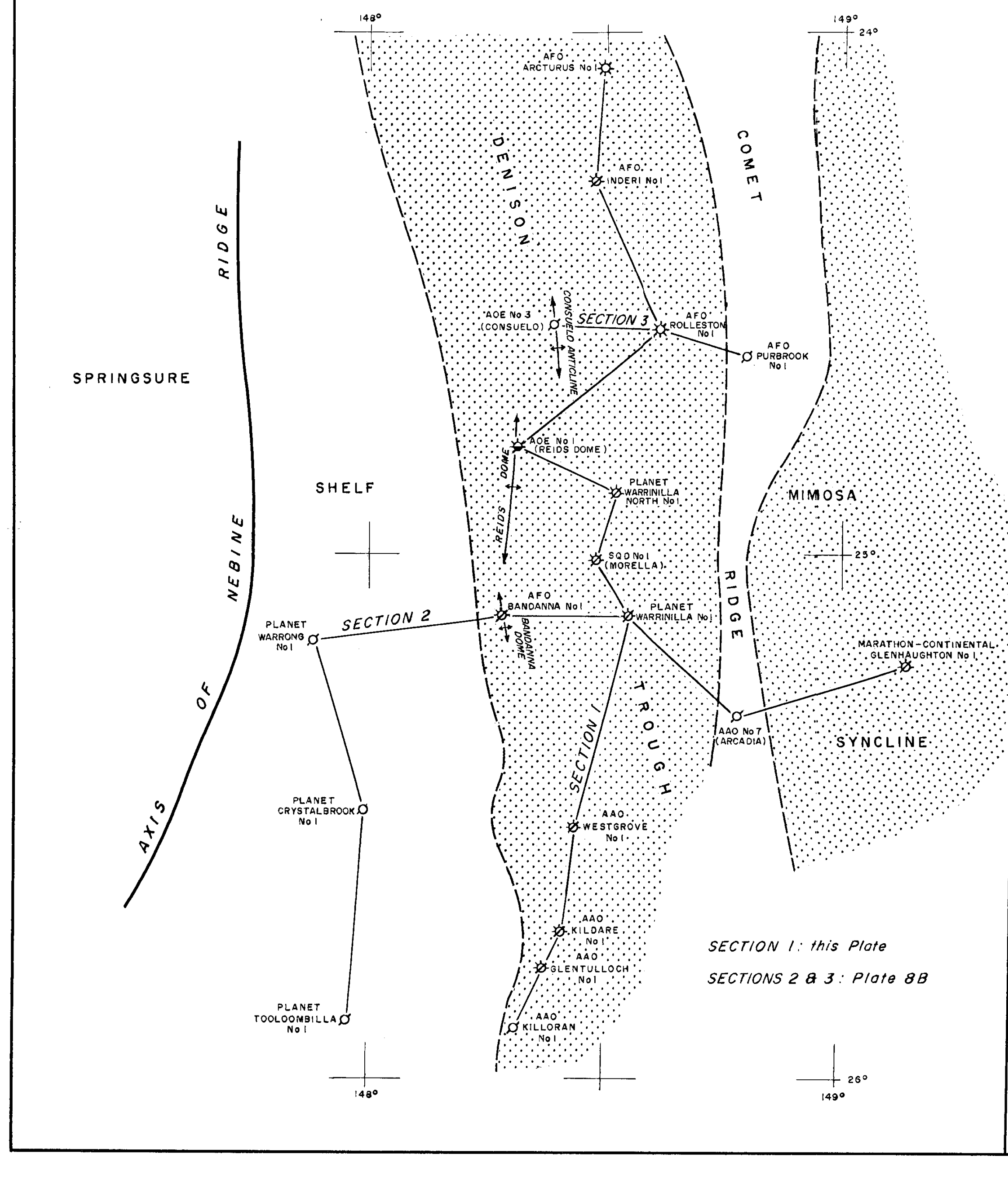
SUBSURFACE CORRELATION OF PERMIAN AND TRIASSIC FORMATIONS IN THE DENISON TROUGH AND ADJACENT AREAS

Compilation and correlation by R. G. Mollan

VERTICAL SCALE

500 0 500 1000 1500 FEET

LOCATIONS OF WELLS AND CORRELATION SECTION LINES



SECTION I: this Plate

SECTIONS 2 & 3: Plate 8B

REFERENCE

Conglomerate
Sandstone
Siltstone
Shale and mudstone
Claystone
Arkose
Calcilutite
Limestone
Coal
Gypsum
Tuff

Basalt
Andesite
Granite and microdiorite
Quartzite
Breccia
SSSSS *Siderite bed*
Fossil wood horizon
Calcareous
Calcareous concretion
Carbonaceous

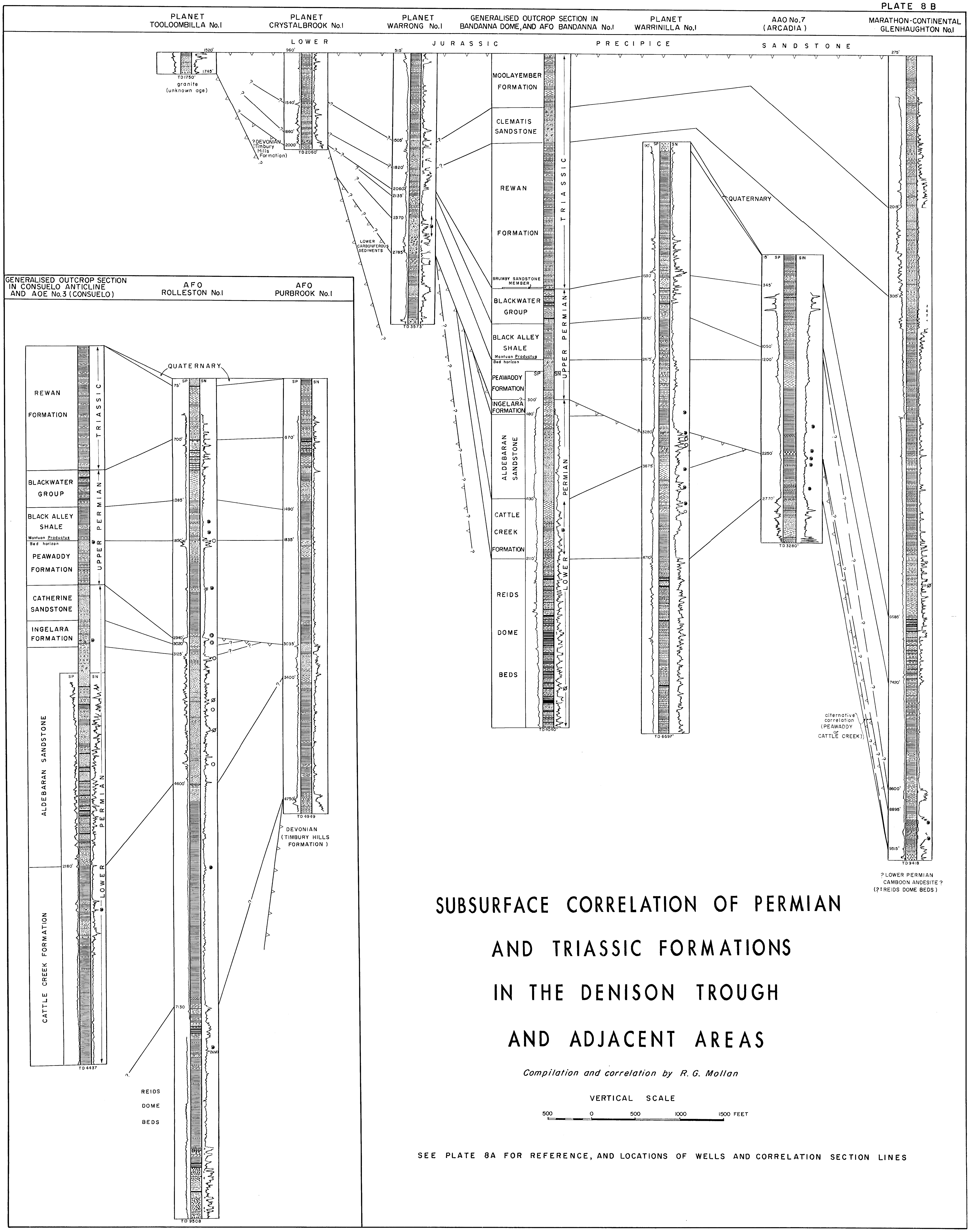
● *Shelly marine fossils (NM=non-marine)*
SN } *Electric logs* *short normal*
SP } *spontaneous potential*
Unconformity
TD *Total depth*

Ø *Gas show (too small to measure)*
○ *Gas show < 1,000,000 cfd*
⊙ *1,000000 – 2,000,000 cfd*
◎ *2,000000 – 5,000,000 cfd*
◉ *>5,000,000 cfd*
● *Small oil show*

Reference to well status symbols in locality diagram

Ø *Dry hole (abandoned)*
Abandoned well with show of gas
Abandoned well with show of oil and gas
☼ *Gas well*

PLATE 8 B



SUBSURFACE CORRELATION OF PERMIAN AND TRIASSIC FORMATIONS IN THE DENISON TROUGH AND ADJACENT AREAS

Compilation and correlation by R. G. Mollan

VERTICAL SCALE

500 0 500 1000 1500 FEET

SEE PLATE 8A FOR REFERENCE, AND LOCATIONS OF WELLS AND CORRELATION SECTION LINES

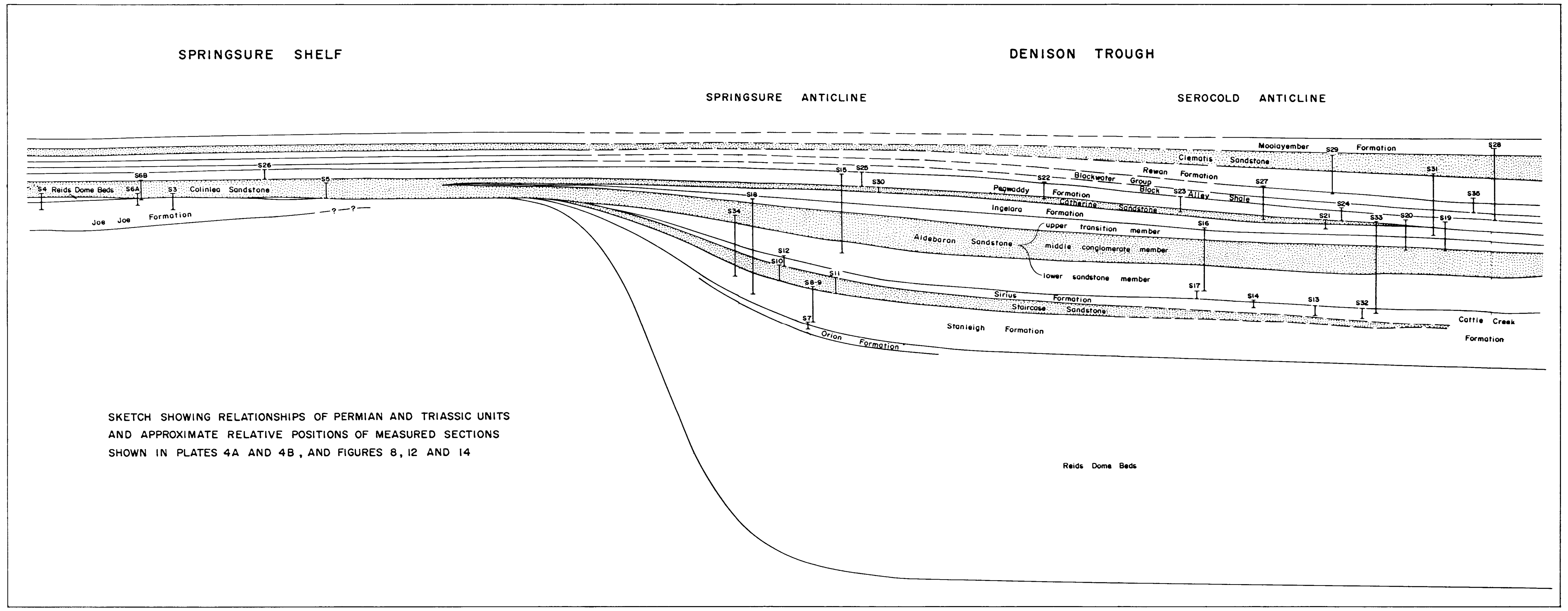
MEASURED OUTCROP SECTIONS OF MAINLY LOWER PERMIAN UNITS IN THE SPRINGSURE AND SEROCOLD ANTICLINES

(All sections located in Plates 7A and 7B)

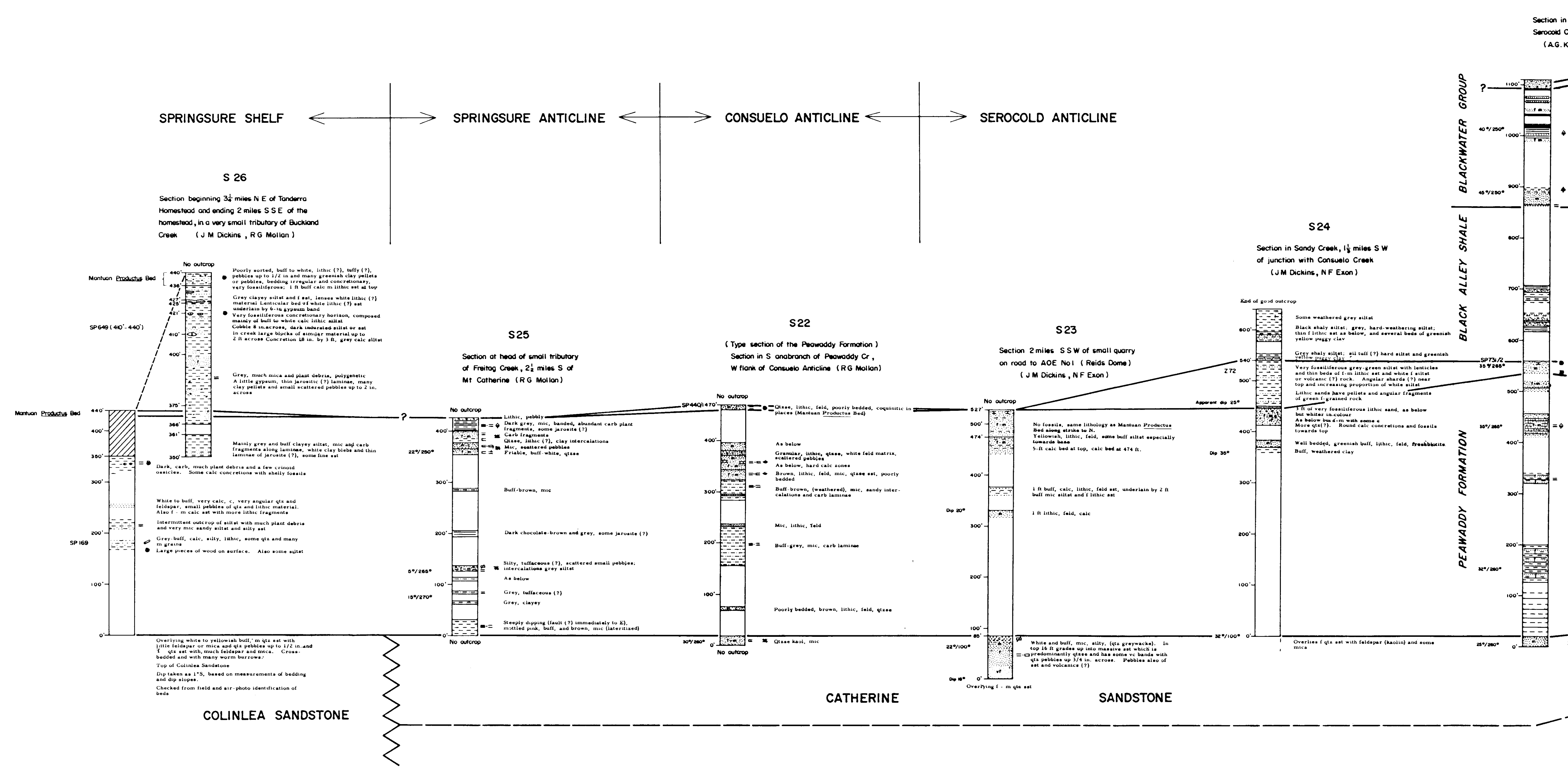
655/A3/67 R.G.W.

MEASURED OUTCROP SECTIONS OF MAINLY UPPER PERMIAN AND TRIASSIC UNITS

All sections located in Plates 7A and 7B except S26 which is located in Plate 6



SKETCH SHOWING RELATIONSHIPS OF PERMIAN AND TRIASSIC UNITS AND APPROXIMATE RELATIVE POSITIONS OF MEASURED SECTIONS SHOWN IN PLATES 4A AND 4B, AND FIGURES 8, 12 AND 14



S 26

Section beginning 3¼ miles N E of Tonderra Homestead and ending 2 miles S S E of the homestead, in a very small tributary of Buckland Creek (J M Dickins, R G Mollan)

S25

Section at head of small tributary of Freitag Creek, 2½ miles S of Mt Catherine (R G Mollan)

S22

(Type section of the Peawaddy Formation)
Section in S anabranch of Peawaddy Cr, W flank of Consuelo Anticline (R G Mollan)

S23

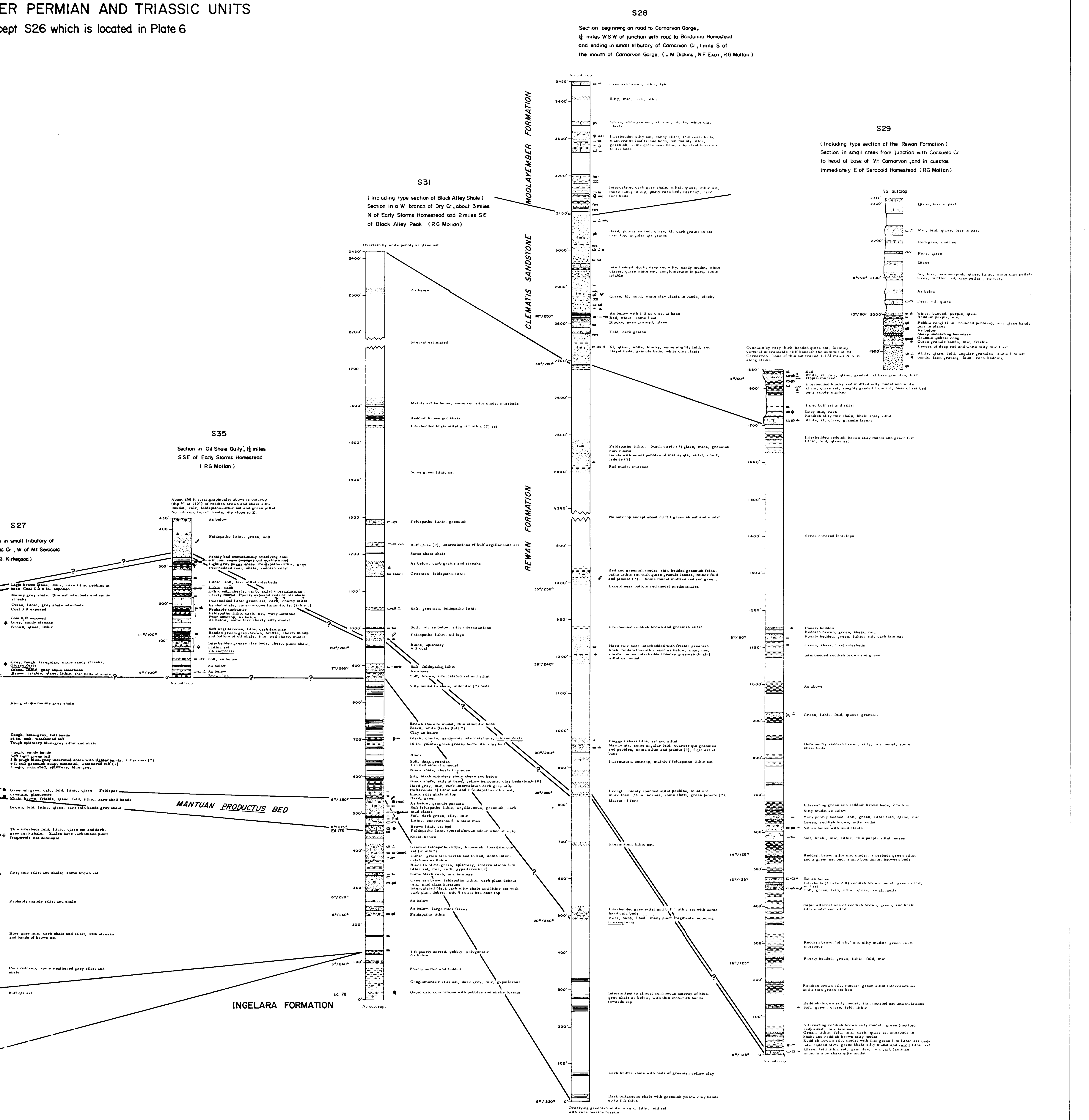
Section 2 miles S S W of small quarry on road to AOE No1 (Reids Dome)
(J M Dickins, N F Exon)

S24

Section in Sandy Creek, 1⅛ miles S W of junction with Consuelo Creek
(J M Dickins, N F Exon)

S27

Section in small tributary of Serocold Cr, W of Mt Serocold
(A.G. Kirkegood)



S35

Section in 'Oil Shale Gully', 1½ miles SSE of Early Storms Homestead
(RG Mollan)

S31

(Including type section of Black Alley Shale)
Section in a W branch of Dry Cr, about 3 miles N of Early Storms Homestead and 2 miles SE of Black Alley Peak (RG Mollan)

S28

Section beginning on road to Carnarvon Gorge, 1⅛ miles WSW of junction with road to Bandanna Homestead and ending in small tributary of Carnarvon Cr, 1 mile S of the mouth of Carnarvon Gorge. (J M Dickins, N F Exon, RG Mollan)

S29

(Including type section of the Rewan Formation)
Section in small creek from junction with Consuelo Cr to head at base of Mt Carnarvon, and in cuestas immediately E of Serocold Homestead (RG Mollan)

G55/A3/68

PLATE 10

GRAIN SIZE (mm)

° ° °	Boulder	>256	Conglomerate
	Cobble	64-256	
	Pebble	4-64	
	Granule	2-4	
c	Coarse	1-2	Sandstone
m	Medium	0·25-1	
f	Fine	0·12-0·25	
vf	Very fine	0·06-0·12	

▤	Siltstone
▦	Mudstone
☰	Shale (fissile mudstone)
▤	Claystone (rock predominantly of clay minerals)
▦	Limestone
▨	Tuff
⌒⌒⌒	Coquinite
■	Coal
▰	Oil shale
V V V	Basalt
⊥	Calcareous lens or bed
■	Carbonaceous bed
⊕	Calcareous concretions
⊙	Ferruginous concretions

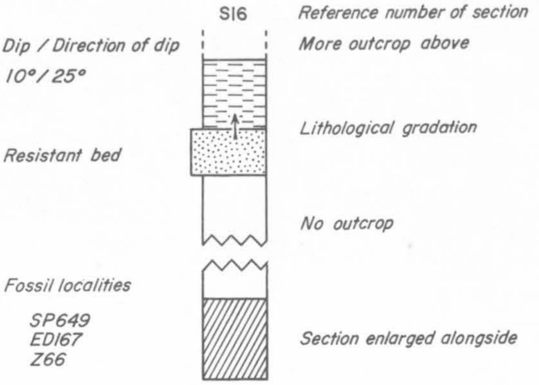
Combined symbols

° °	Conglomeratic sandstone
▨	Tuffaceous siltstone
◎	Shelly fossils
♀	Plant fossils
⌀	Fossil wood
⊳	Fish scales

BEDDING FEATURES

		Thickness (in.)
⌀	Very thick	>40
▭	Thick	12-40
⊏	Medium	4-12
=	Thin	0·4-4
≡	Laminate	<0·4

≚	Cross-bedded	≦	Cross-laminated
⌣	Festoon-bedded	↑	Graded-bedded
∞	Undulate	∽	Slumped
⊎	Scour and fill	∿∿∿	Unconformity
⊔⊔⊔	Ripple marks - oscillatory	⋀⋀	Ripple marks - current
⊓⊓⊓	Fluting	Ʊ	Load cast
※	Worm trails and casts	⋓	Worm burrows



Most sections measured by Abney level; some by, or supplemented by, barometer and dip and chain, pace or air-photo distance

ABBREVIATIONS

Calcareous	calc
Carbonaceous	carb
Claystone	clayst
Conglomerate (ic)	conglom
Feldspar (thic)	feld
Ferruginous	ferr
Kaolinitic	kl
Limestone	lst
Micaceous	mic
Mudstone	mudst
Quartz	qtz
Quartzose	qtzse
Sandstone	sst
Siliceous	sil
Siltstone	siltst

Reference to Columnar Measured Sections